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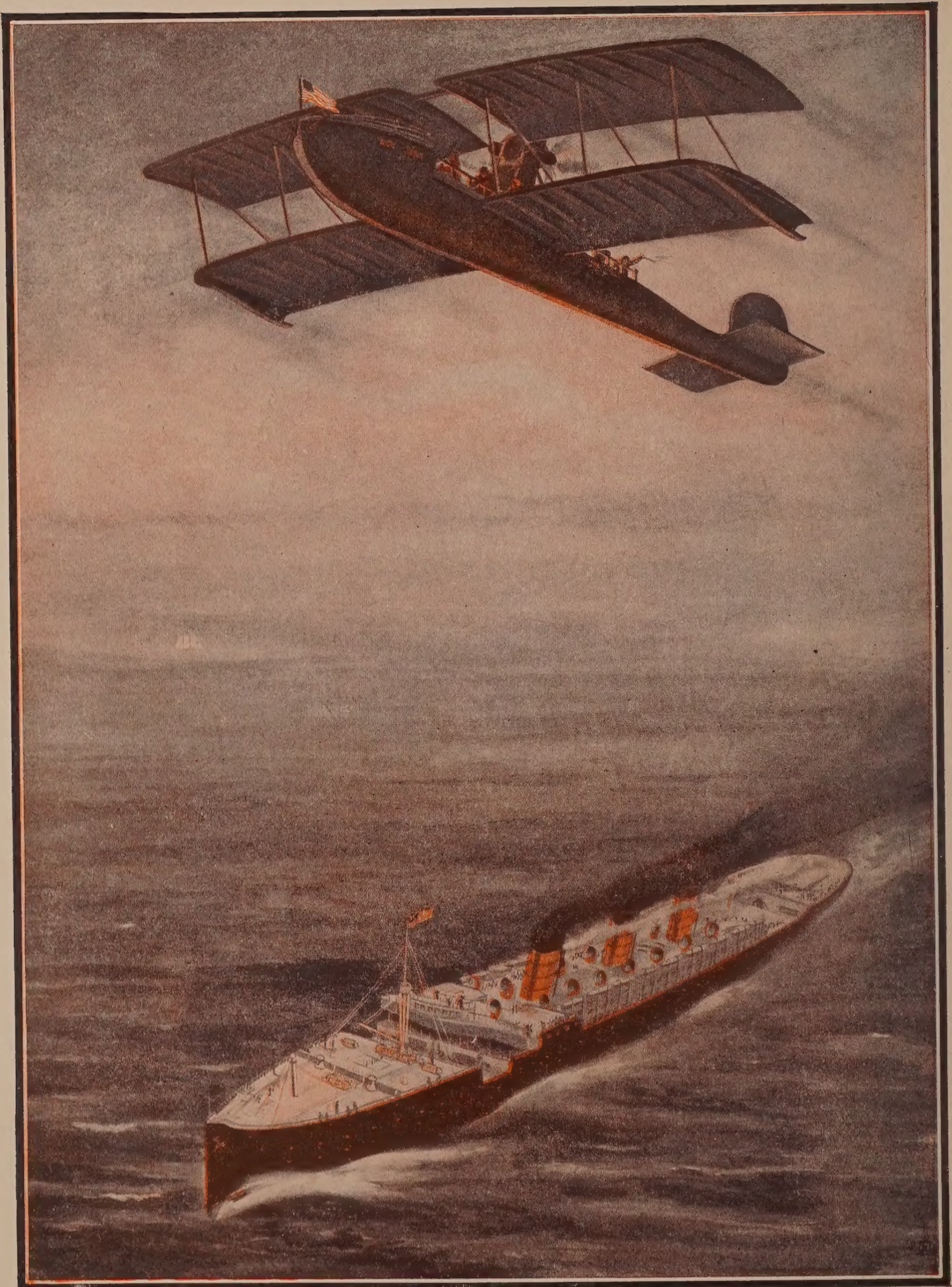
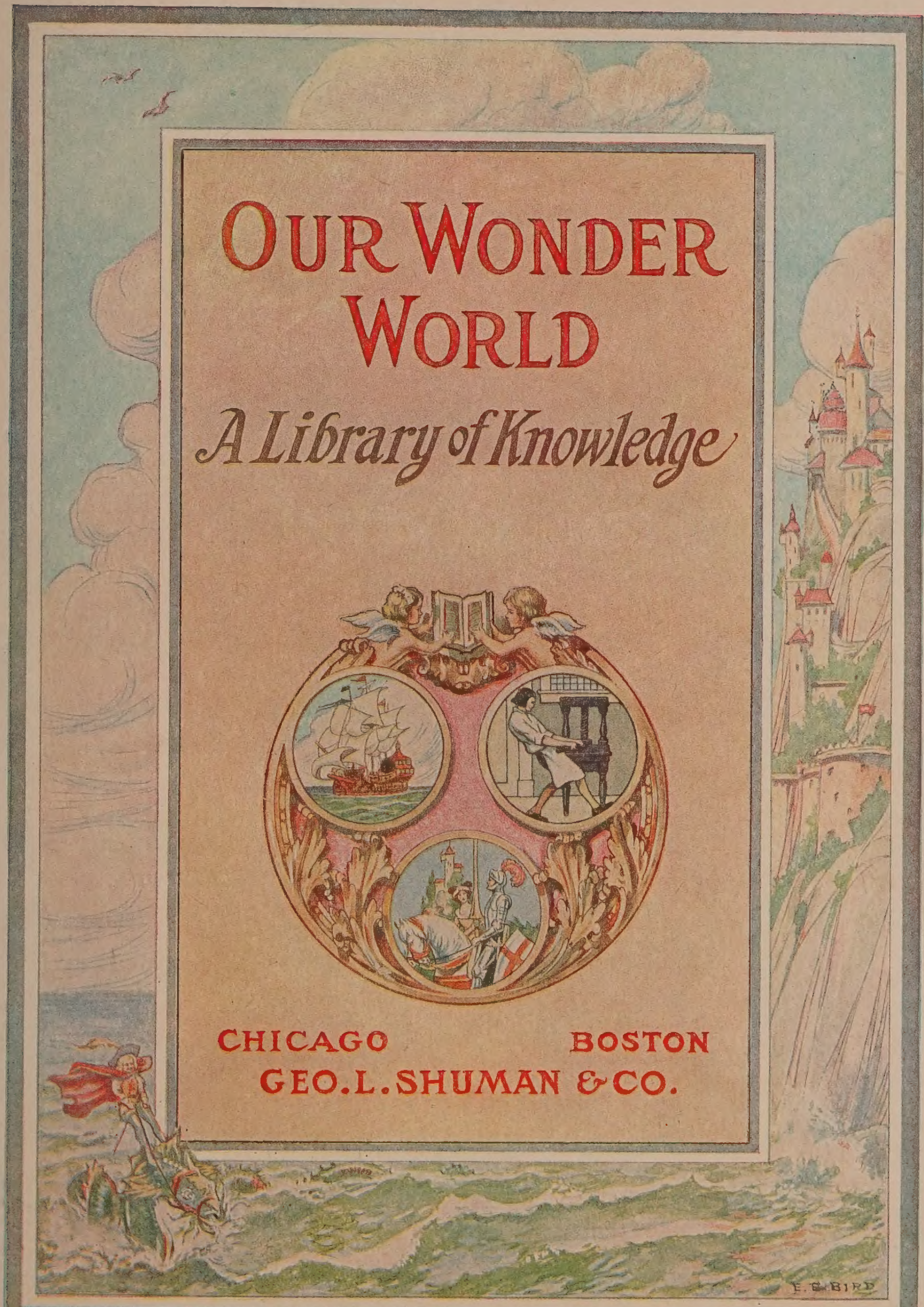
VOL. II



A MID-OCEAN SCENE



OUR WONDER WORLD

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VOLUME TWO

INVENTION AND INDUSTRY

Into the dust of the making of man
Spirit was breathed when his life began,
Lifting him up from his low estate,
With masterful passion, the wish to create.
VAN DYKE

ACKNOWLEDGMENTS

The illustration of a volume on "Invention and Industry" requires not only the photographs obtainable through the usual channels, but also pictures showing the inner workings of machinery, views of the interior of manufacturing plants, and of the various operations through which raw products are passed on their way to completion. We are indebted in this volume to many firms and individuals, of whose courtesy mention has been made in many cases in connection with the pictures used. But it would be impossible to list the many readers of different sections of the text to whose helpful and suggestive criticisms the book owes much. In a world in which such constant advances are being made each year and each month in the construction of machines, in the processes of industry, and in the emphasis on one invention and another, no single volume, however carefully watched and frequently revised, can present every subject as fully and as elaborately as might be desired. The purpose in this volume has been to present general principles, illustrating them by descriptions and pictures of typical machinery. It is hoped and believed that from the setting forth of these principles, with their examples in everyday practice, the reader will gain a new interest in the inventions and industries which minister to his comfort and convenience, and an intelligent background for his appreciation of forthcoming inventions.

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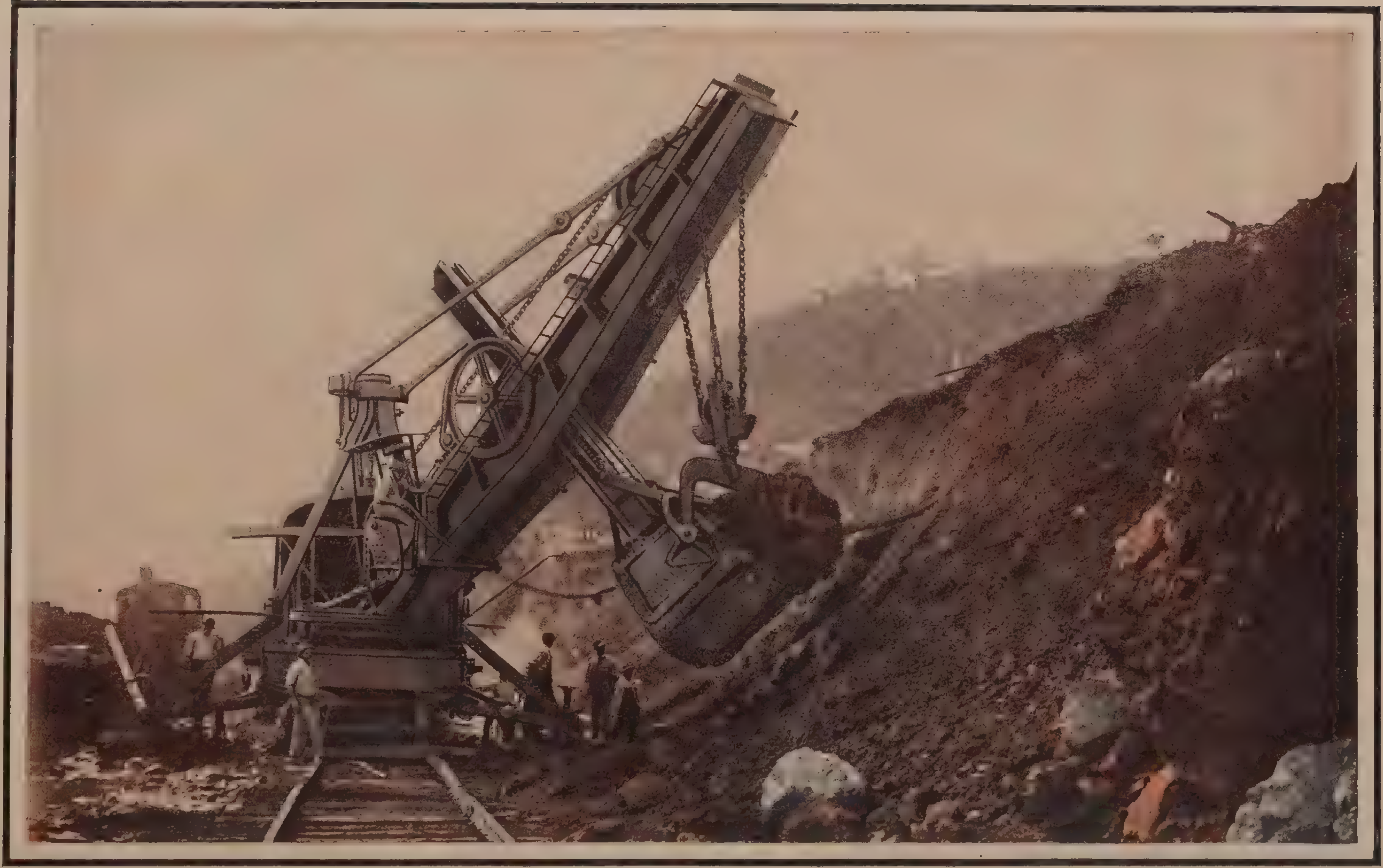
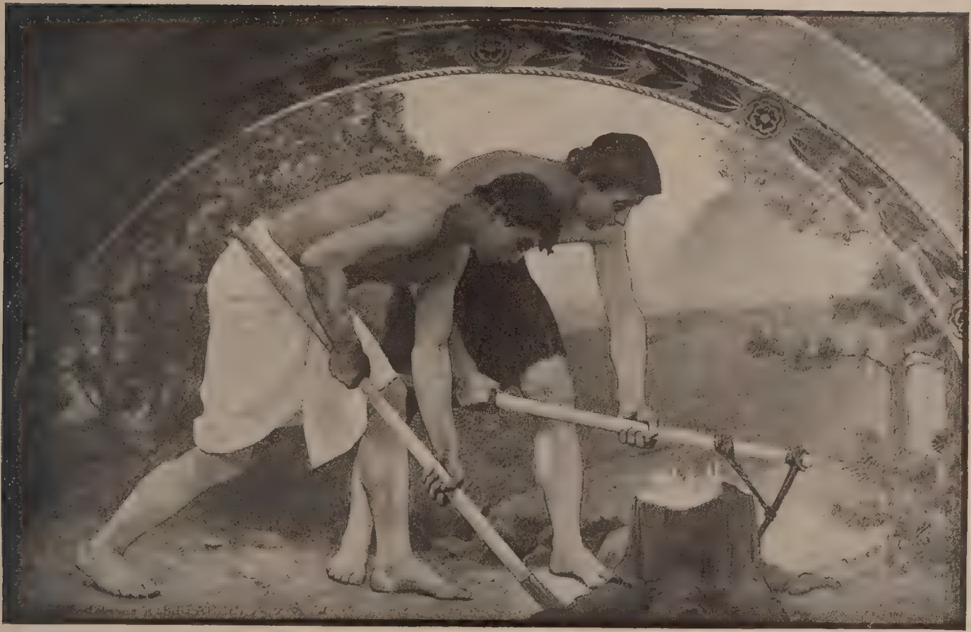


A MONSTER STEAM SHOVEL AT PANAMA, SCOOPING UP A CARLOAD OF GRAVEL



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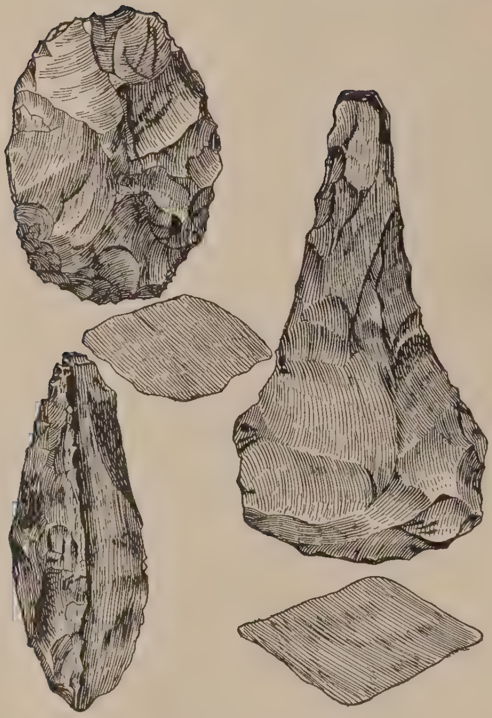
MAN'S EARLIEST INVENTIONS

THE first man was indeed a child of Nature. Naked upon the naked earth, he was fed and sheltered by it as if it were his mother. Yet Nature was his enemy as well as his friend. He must fight the wild beast, avoid the serpent, and watch for dangers on every side. The falling tree might crush him, the river drown him. Nature's forces would help him if he used them rightly, or would harm him if he did not; and like the wild beasts among which he lived, he must learn to avoid dangers or be destroyed. But man after a time began to do more than this. In simple ways he used his wits to make the forces of Nature aid him. In doing this he began to make tools — a trait which no other creature of earth has shown.

THE EARLIEST TOOLS OF MAN

When first a man picked up the broken limb of a tree and used it as a club, or threw a stone at a wild beast that threatened him, the age of invention had begun, a period that was to lift him far above the level of the beasts among which he had his origin. It is through the invention of tools and their use that man has grown from a child of Nature to the civilized adult of to-day with all his mighty force of intellect.

Man alone of all creatures thinks of things as tools and uses them as such. Through his inventive genius a stick became a club with which he defended himself from the wild beast and killed the venomous serpent. Soon he saw that if it was sharp he could thrust with it, and he had a spear. Then he threw it, point first, and had a javelin. Simple as this seems to us now, each step in advance was a tremendous one for primitive man; and when, perhaps ages later, some man found that he could bend another stick with a cord stretched from end to end and shoot the javelin from that, thus having a bow and arrow, how great a farther advance that was. But that could happen



TOOLS OF THE STONE AGE

only after men had made many other inventions, for to have a cord — even the sinew of a deer, a long strip of deer hide, or a cord of twisted strong grasses — meant other inventions to lead the way. Before a strip of rawhide or a sinew might be used, man must have had something that would do for a knife. So the beginning of all inventions, the very primitive sharp stick with which to jab an aggressive beast, or the stone to throw at him, led man on, step by step, to all the weapons and tools which have come after.

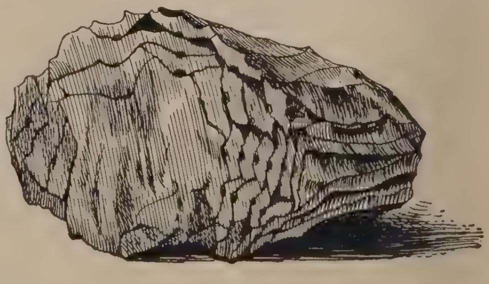
Primitive man could cross shallow rivers by wading, but some streams were too deep, too swift, or too wide for wading or swimming. Across the swift, narrow ones he could find, no doubt, a fallen tree and thus get the idea of a bridge. Across the wide, placid ones he could float on a fallen log and thus find his first ship supplied by Mother Nature. All bridges and all ships have grown from these two simple means, through the inventive genius of men, in the same way as the stone which was his first hammer, which when it had a sharp edge became his first ax and when it was sharp and slim was a knife, has expanded into all devices of cutting tools through successive inventions.

THE AGES OF STONE

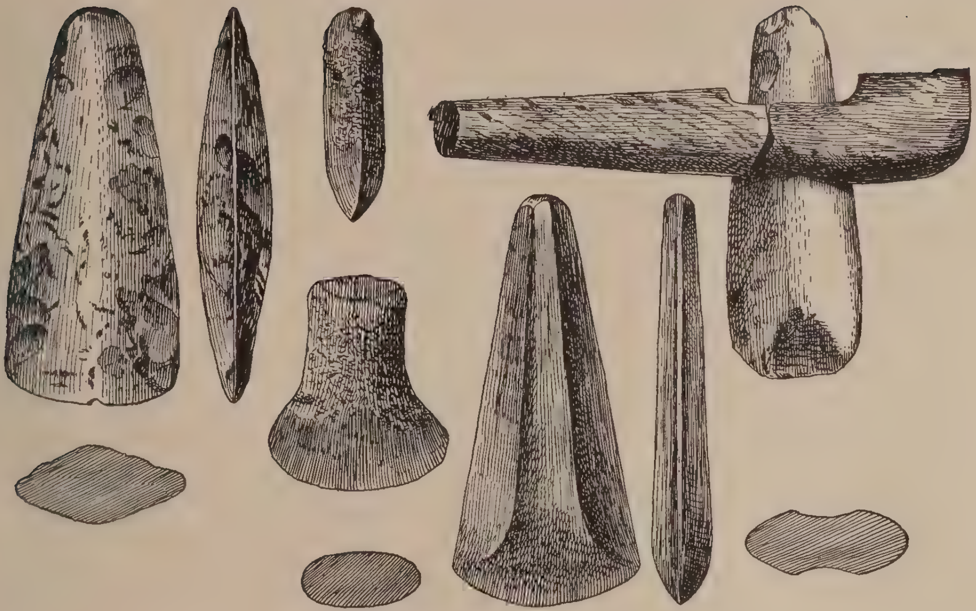
The first men of whom the earth has left us any record were those who used rough, chipped stones for weapons and tools. These stones are dug from the earth in many places and show that the men who used them lived in those localities. For many thousands of years men lived on with only these rough stones for axes and knives, for spear and arrow heads, and we call that age the Rough Stone Age. Then they began to polish the tools by rubbing them against other stones or with sand, and we have the Smooth Stone Age.

HOW DID THE STONE AGE MAN SHAPE HIS FIRST IMPLEMENTS?

Wherever primitive man has dwelt, we are quite sure to find tools of flint. For the Stone Age inventor discovered that this mineral breaks readily into flakes with sharp, smooth edges. It was not beyond his skill to secure flakes of good size and to shape them to his simple needs. A glance at the drawing at the foot of this page shows how he went to work. Many of the most beautiful flint tools that we find are those that were made by the North American Indian, for savage man has been much the same in all ages and lands. At Icklingham, in England, the manufacture of gunflints is still carried on, for export to South Africa. The method is the same as



FLINT CORE WITH FLAKES REPLACED UPON IT



TOOLS OF THE LATER STONE AGE

These are good specimens of the celts, as they are called (from the Latin *celtis*, "chisel"), implements in common use by men of the Stone Age. Their flat blades were designed for cutting timber, killing animals, and other purposes.

that used by the Stone Age man. The workman takes advantage of the peculiar structure of the mineral, and his skill consists in adjusting the force of his blow to the size of the flake which he wishes to remove. Boys will find it a very interesting experiment to try their own skill on the flints which can be picked up in most gravel banks.

THE GREAT GIFT OF FIRE

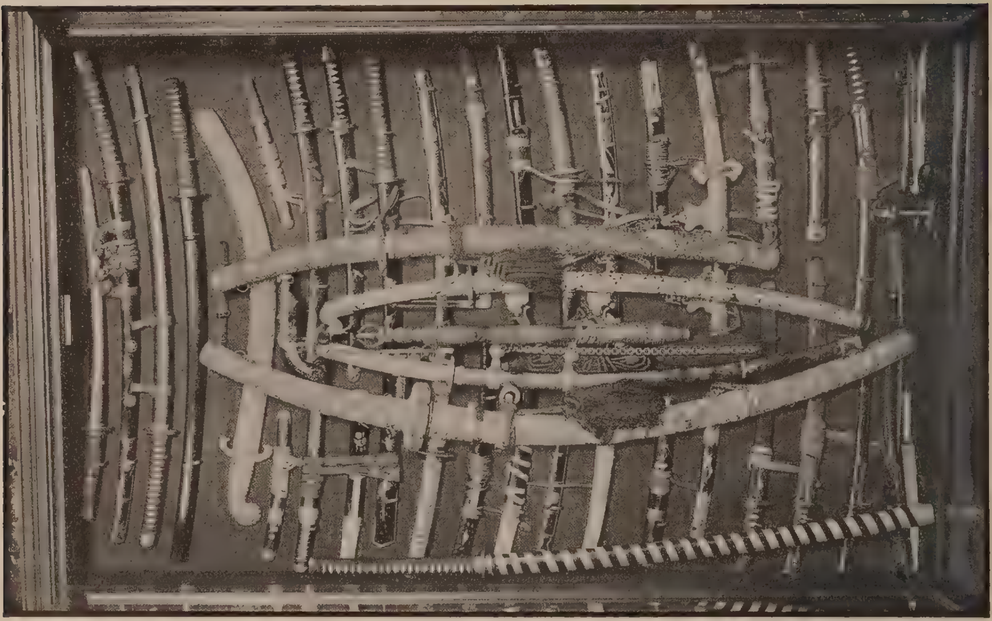
The ancient legends have it that fire first came to men from heaven as a gift of the gods. Fire was, indeed, a great gift to man, and no doubt it first came from heaven in the shape of lightning, which often sets fires to-day. Yet when lightning set fire to the forests and swept all before it in terrible death, it must have been a bold and inventive primitive man indeed who dared to try to use this scourge. The beasts to-day flee from fire and dread it, as they have always done. Yet man has learned to master it and make it tremendously useful to him. First he used it for warmth, then for cooking his food, and later, no one knows how many thousand years later, finding that heat would convert water into steam, began to use it to help him in his inventions.

THE BRONZE AGE

After this came the Age of Bronze. Man found that his servant, fire, would melt certain stones and leave behind a metal which could be shaped into far better tools than he had ever had before. This was a mixture of copper and tin, such as could be smelted from the ore with a moderate heat. The Bronze Age has left us many relics of the work of these early men who made not only tools and weapons, but household utensils of many kinds, and showed a great advance over the men of the Polished Stone Age which preceded theirs.

THE "LOST ARTS"

To this period belong many of the so-called "lost arts," which we, with all our modern



A COLLECTION OF SWORDS WITH CARVED HILTS AND BLADES

skill, have sought in vain to recover. Among these is the very important art of tempering bronze, which might be quite as useful to us as to the men of the Bronze Age. Another lost art is that of engraving on very hard gems. Our modern cameos are cut in shell, or onyx, but the ancients were able to carve exquisite designs on the hardest of precious stones. There are many other lost arts which belong to the Bronze Age, or times but little later. Among these was an art of painting in wax so that the exposure of ages has scarcely dimmed the color of the paintings. In fact, men of the Bronze Age were very cunning workmen, and not inferior to us in skill of hand or artistic feeling. Homer's description of the bronze shield of Achilles is probably an invention of his own imagination; but just such beautiful work must have been familiar to the poet's audience, or they would not have believed his account.

THE IRON AGE

But man, continually advancing in inventive genius, found that iron, which may be made from the ore only by a far greater heat than bronze, could be melted out of his primitive furnaces and shaped into much harder and keener tools and weapons.

Thus came the Iron Age in which we live to-day, with all its wonders of inventive genius crowding one upon another so rapidly that day by day, almost, we are astounded at the progress made. Within little more than a century we have seen the vast development which has come from the application of steam as a motive power to machinery, and within half that time we have seen electrical inventions so increase as completely to overshadow the wonders of steam.

It is hard for us to understand how men lived without those things which we now enjoy; but to each generation its own time is the most wonderful of all. Indeed, many early inventions brought about greater changes than are ever likely to come from future discoveries. The greatest of these epoch-making devices was the alphabet, invented by the Phœnicians; but in this volume we are to tell only of mechanical inventions.

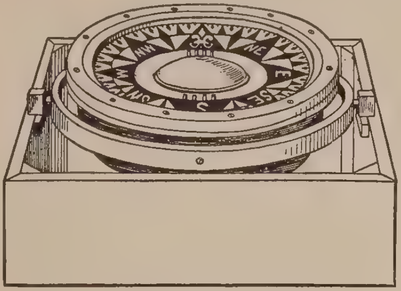
THE EDISON OF ANTIQUITY

The wizard of antiquity was Archimedes, a Greek who lived in Syracuse in the third century B.C. Archimedes invented so many things and was so far in advance of his age that some of his ideas seem almost modern. Most of his practical inventions of which we know were for use in the wars of the Syracusans. But perhaps the most important inventions of early times were those having to do with navigation — the anchor and the compass. The anchor is a simple device of metal so shaped that the pull of the cable by which it is attached to the ship tilts it upward and causes the flukes to be buried in the mud. Without this device navigation would have been confined to small boats, as in the days of the Homeric heroes, who drew their ships from the water each night.

THE MARINER'S COMPASS

It seems to be well proved throughout the history of mankind that it is a mechanism that makes an era. Among savages, for instance, those tribes who use the bow and arrow, though side by side with those who do not, in the jungle, are living in a later and more advanced age of the world. In ancient times the making of weapons and tools of iron lifted nations far above those who still used bronze, just as the invention of bronze had lifted others far above those who used stone only. So the mariner's compass ushered in a new era. It gave the sailor courage to sail forth on uncharted seas and opportunity to discover new lands, starting an era of exploration and colonization that will endure until the last corner of the remotest sea is charted, the last habitable land occupied by civilized colonists. With the use of the mariner's compass began modern times.

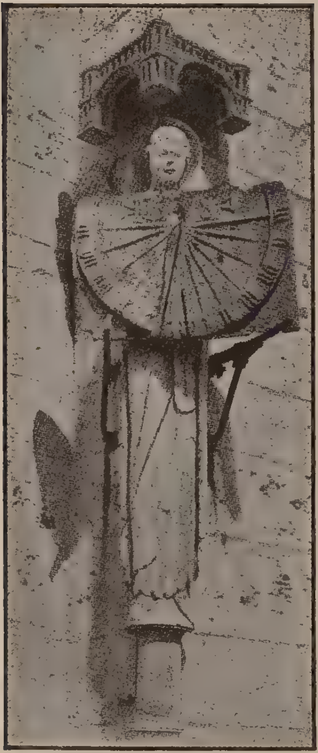
It has been known for ages that a magnetized substance, if suspended and allowed to turn freely horizontally, would point north and south. That is what the mariner's compass is, though as it is now used one does not think of it so much as a needle as a dial with many points. However, that is the principle on which the modern compass is built. Nor does the needle point to the true poles, but to the magnetic poles of the earth, which are situated at some distance from the true poles. Hence mariners using the compass must allow for its "variation," and thus find the true north by calculations based on experiment and observation in various parts of the world. In most portions of the seas usually sailed this variation is slight, but there are certain parts of the earth where it is very great. These regions are difficult of access, being in the far north, but it is possible to reach portions of the northern hemisphere where the magnetic needle points west instead of north. In other places, west of the magnetic pole, the compass points east; while if one were on a line between the true north pole and the north magnetic pole, he would find the compass pointing due south. However, the variations of the compass, great and small, have all been figured out and may be easily obtained by any navigator.



THE MARINER'S COMPASS

An interesting experiment, showing the principle on which the compass is founded, is to take a common needle, magnetize it by the use of a small magnet, stroking it the same way for a few times with the magnet, then oil it and float it gently on the surface of a vessel of water. The surface tension of the liquid will hold up the needle, if it be carefully placed there, and it will point to the magnetic pole.

A ship's compass rests in a stand called a "binnacle." It consists of two or more "needles" which are composed of thin layers of steel or bundles of steel wires, magnetized. These are fastened to the under side of a card on which the main points of the compass and thirty-two subdivisions are depicted. This card is delicately balanced and swings with



SUN CLOCK ON CHARTRES CATHEDRAL

the motion of the needles so that the point marked N points always to the magnetic north. The whole is inclosed in a brass case which again is suspended by two concentric brass rings so joined that, however the ship swings, rolls, or tosses, the compass card will always be level. The compass on a ship in motion is watched day and night by the helmsman, who sets his course by it.

HOW DID THE ANCIENTS MEASURE TIME?

The sundial was invented by Anaximander in the seventh century B. C. It answered every purpose for measuring time until the hourglass was devised, which was more accurate for the measurement of short periods, from three minutes to an hour. Clocks were invented sometime in the eleventh century. A clock made in 1348 was exhibited, going, at the Centennial Exhibition of 1876. These ancient clocks were in all respects similar to our own. They did not use a pendulum, which was not invented until several centuries later. Some attribute this device to Galileo, the great astronomer; others to a London clock maker named Harris. It is probable that Galileo first observed the regularity of the swing of the pendulum, and that Harris made the first practical pendulum clocks. The first clocks were tower clocks. One was placed in Westminster Abbey in 1288. Henry VIII gambled away its beautiful bells!

THE HISTORY-MAKING INVENTION OF GUNPOWDER

Gunpowder was invented by the Chinese, we do not know just when. They, however, made no important use of their discovery. But when it was rediscovered by Schwartz in 1320, it changed the course of history. Until then one man-at-arms in full armor was superior to a whole troop of rudely armed peasants. As only the rich could buy armor, the power of the great over the masses was irresistible. But gunpowder changed all that. Armed with his gun, one man became as formidable as another. The invention of cannon preceded that of handguns. The first guns were so heavy and clumsy that they were almost as dangerous to the shooter as to his enemy. By the beginning of the eighteenth century the gun had become an efficient weapon. Armies were reorganized and the era of modern political history began. The great military genius of this period was Frederick the Great of Prussia. It was he who adapted army organization to the use of firearms.

Gunpowder was known to the nations of the Far East,

A COLONIAL CLOCK

to China and India, at a very remote period in history. In a crude way these nations applied it to firearms, though the results were more likely to frighten than harm the enemy against which the weapons were directed. The "Greek fire" of the Byzantine emperors and the "terrestrial thunder" of the Chinese may well have driven hordes of barbarians before them in fear of the flashing flames and the astounding noises, even if they did them no bodily harm.

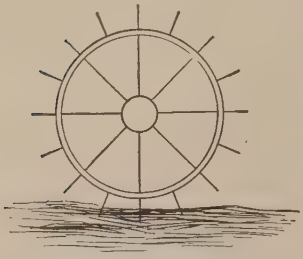
The composition of this gunpowder used by the Chinese long before the Christian era does not materially differ from that of the gunpowder of to-day. Roughly it consists of three quarters potassium nitrate and one quarter divided between charcoal and sulphur. The burning of one volume of this powder produces 296 volumes of mixed carbon dioxide and nitrogen which, expanded by the intense heat of the explosion, are further increased to fifteen hundred times the volume of the powder burnt. This expansion it is which forces the projectile through the tube of the gun or rifle and sends it on its way with such force. But the amount of force depends on the rapidity with which the powder burns, and it was not until Bertholdus Schwartz in 1320 taught the nations to compress the powder and then granulate it that firearms became effective. Immediately after this discovery cannon appeared in the armory of almost every state, as if their use had been known previously but they had not been considered practical because of the bad quality of the powder manufactured.

MUZZLE-LOADING CANNON OF PERIOD OF MEXICAN WAR

Now at Charlestown Navy Yard.

Like many inventions which have revolutionized the progress of the world, Schwartz's seems a simple matter; yet in the end it made a tremendous force, which had been known as a possibility for perhaps a thousand years, directly available as a servant of mankind. The use of gunpowder as an explosive in blasting and in other ways having no connection with firearms or war led directly to the invention of other stronger explosives, notably dynamite, which is a wonderfully effective agency in the work of the world to-day.

EARLY USES OF POWER — WATER WHEELS



A WATER WHEEL

A cubic foot of water weighs about sixty-two and one half pounds. Think of the immeasurable weight of water that pours over Niagara Falls, and of the amount of energy every cubic foot represents, and you will not wonder at the statement that if all this power could be used, Niagara alone could furnish power enough to light the world with electricity.

Water wheels were first used by the Chinese. They were employed to raise water for irrigation purposes and were made of buckets and bamboo poles. Mention is made of the use of water wheels about 70 B. C. These were constructed of a few vanes or boards fastened to the end of a millstone spindle and were moved by the impact of a current of water, thus turning the spindle. Tide mills were known in Venice as early as 1046. In China, Egypt, and Assyria current water wheels were used many centuries ago. These wheels have flat vanes which dipped into a moving stream of water, as shown in the figure above. A large wheel of this type was used to pump the water supply for London about 1581.

These primitive wheels have gradually given place to the modern water turbine, the principle of which was first successfully employed by Fourneyron, a Frenchman, in 1827, but which did not come into commercial use until about 1850. In the modern turbine, stationary guide vanes direct the water flowing into the rotating wheel. As this water flows through the runner, its velocity or speed is changed both in direction and magnitude. This change gives the force which turns the wheel.

A type of water wheel known as an "impulse" wheel is shown on page 9. This wheel has on its rim bucket-shaped vanes or blades against which a stream of water is directed from a nozzle placed at right angles to the shaft on which the wheel turns and pointing horizontally at the lowest buckets. The impact of this rapidly moving stream of water on the blades causes the wheel to revolve at a high speed. The buckets, as shown in the figure, are divided vertically in the middle, and the jet of water striking this partition is thrown to either side after doing its work on the wheel.

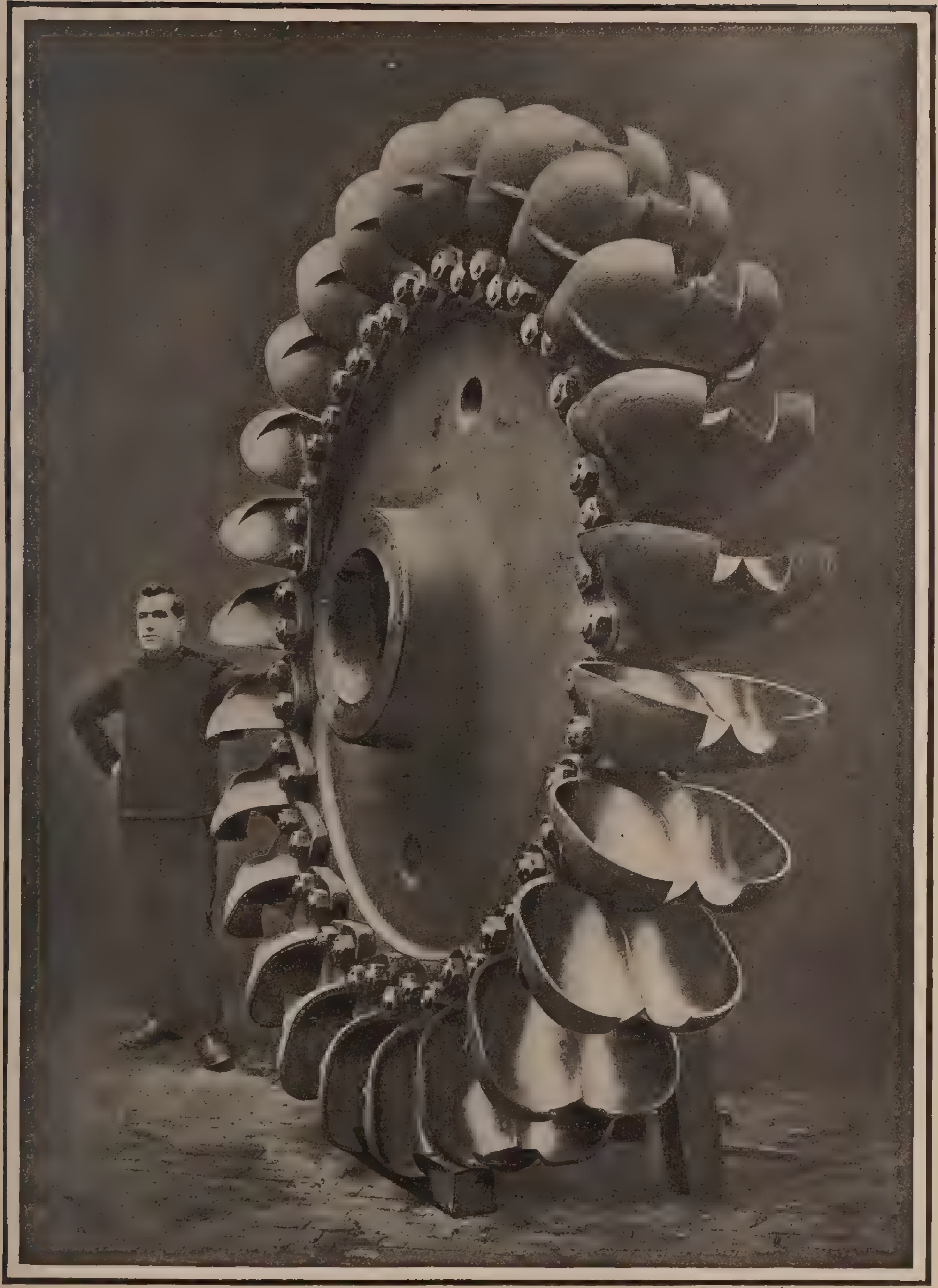
The discovery that by the aid of an electric dynamo the power generated by the water turbine can be transferred through long distances bids fair to make this form of power one of the most important factors in the doing of the world's work.

WIND POWER

The most familiar example of the use of wind in generating or producing power is the windmill, which dates back to the twelfth century. It is still to be found in agricultural districts, in spite of all the developments of steam and electrical power. A windmill is a series of inclined planes forming the spokes of a wheel. A gearing is so adjusted to the axle that the power may be utilized, as for grinding or pumping. But the windmill goes only when the wind blows, and hence this power cannot be depended upon where a steady supply is necessary. Its cheapness will keep it in use for certain purposes, and if windmills went out altogether, a country like Holland would lose much of its picturesqueness. But wind power is no longer reckoned important among the motive powers of the world.

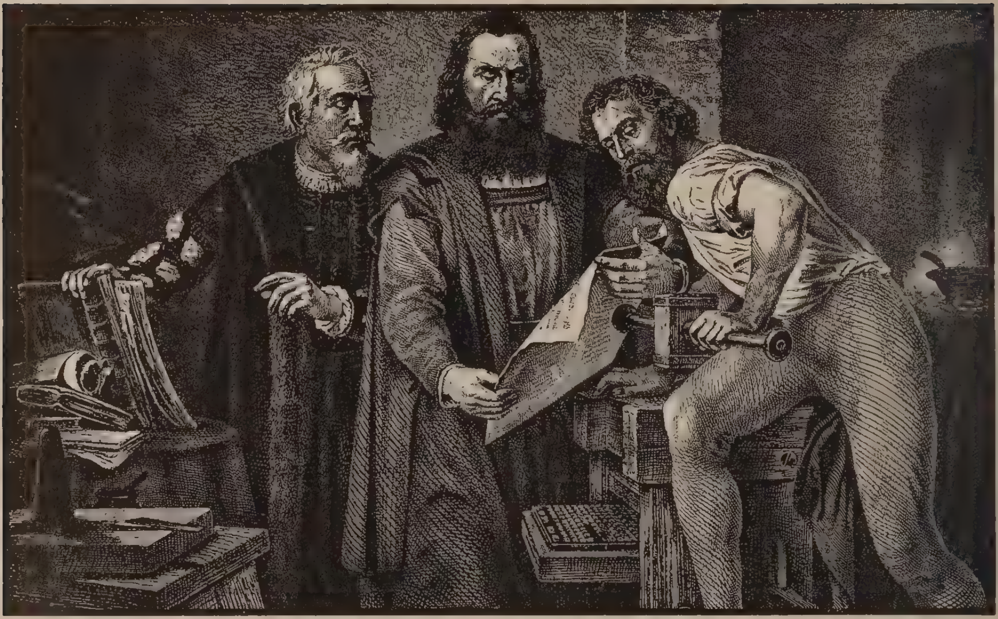
THE ORIGIN OF PRINTING

The art of printing dates back only a few centuries, although a kind of printing from solid blocks, instead of movable types, has been in use among the Chinese from very ancient times. Printing from movable type is said by the Dutch to have been invented by Lourens Coster in 1420, but the Germans claim that it was invented by Johann Gämsfleisch, of the Gutenberg family, in 1438. The inventor is known generally by the name Gutenberg. Within twenty-five years the invention was known and practiced in the leading cities of Europe. William Caxton introduced printing



Courtesy of Scientific American

A 7500-HORSE-POWER IMPULSE WATER WHEEL



THE FIRST PROOF FROM GUTENBERG'S PRESS

into England, setting up a press in Westminster Abbey. A picture of his workshop is given in Volume VIII, page 72.

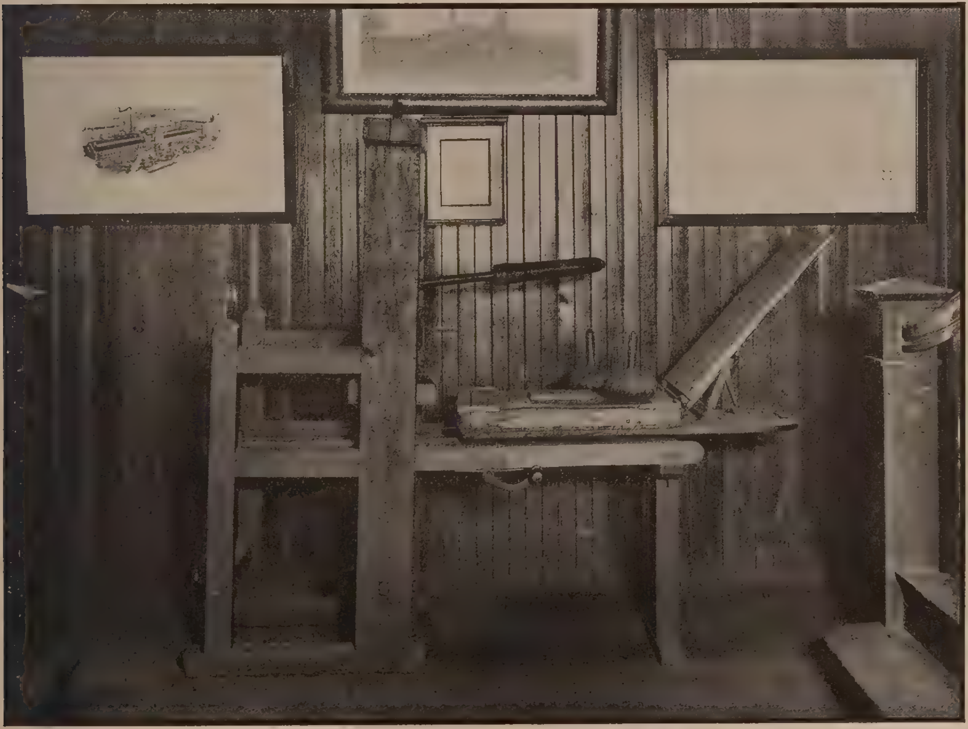
For more than two centuries little or no progress was made in the method of printing, although many famous printers flourished during that time. The most noted of these were the Dutch printers Aldus and Elzevir. The work of these and other early printers is often very beautiful and exact, and is seldom equaled in the printing of our own time. The reasons for this are, first, that the work was all hand work, slowly and carefully done; secondly, the paper used was a beautiful handmade linen, paper which would be too costly for use to-day; and, in the third place, the printers made their own type, and but few impressions were taken from the same type. But the real superiority of early printing came from the fact that the printers were themselves leading scholars, and took an intense interest in the accuracy and beauty of their work. The pioneer printer of the United States was Benjamin Franklin. He invented a hand press which, with very little modification, is still used in most printing offices for taking first proofs from plates and type.

The first centers of printing were Antwerp, Leyden, Paris, and Venice. In these cities originated most of the early types. The style known as "italic" is said to have been a copy of the handwriting of Petrarch. Most of the types used in England came from Holland. The great University Press of Oxford, England, still casts type from a set of molds imported from Holland. This type is reserved for their best publications and is of great beauty. The molds are of brass into which the form of the letter has been struck by a steel die. This gives a very sharp, clean edge to the letter. The metal ordinarily used is an alloy of tin, and antimony with lead. The early printers applied the ink to the type with a brush, as you would blacken a stove. The paper was dampened and laid on the type by hand. The pressure was applied by a screw or lever. Slow as this laborious process was, how marvelously rapid it must have seemed to those who had been accustomed to books lettered with a pen by hand!

HAND SPINNING AND WEAVING

Little more than a century ago every girl was taught the graceful art of spinning, and she learned, too, to weave; for on her skill at these arts would depend the clothing of her household after she married. It seems hard to believe this nowadays, when great factories turn out enormous quantities of beautiful fabrics daily and the art of spinning and weaving by hand is almost entirely a forgotten one. Yet from the most distant times, until modern invention changed it all, spinning and weaving were household occupations. In ancient mythology the three Fates—Clotho, Lachesis, and Atropos—were represented as spinners, the one holding the distaff, another twisting the thread, while the third cut it off when life was finished. On the earliest Egyptian monuments we have representations of the spindle and distaff—primitive spinning tools as compared with which even the spinning wheel of our grandmothers was a great improvement. The distaff, on which was placed in a fluffy mass the material to be used, was held in one hand while the spindle was whirled in the other with a bit of the fluff attached and gradually drawn away. This made the thread. In the spinning wheel the spindle was set in a frame which was made to revolve rapidly by a big wheel and a crank operated by a treadle. With this the spinner used both feet and hands and, becoming expert with long practice, was able to spin a much larger amount of thread in a day. As late as the beginning of the last century a modification of such a spinning wheel was largely in use in many countries.

But we must not think that our forefathers



OLD-FASHIONED HAND PRESS, USED FOR TAKING PROOFS

On exhibition at Norwood Press, Norwood, Mass. This press is identical in style with that invented by Benjamin Franklin and dates from Franklin's time.

FLAX SPINNING IN EARLY NEW ENGLAND DAYS

were interested only in war or the absolute necessities of life. Many beautiful works of art were wrought on the old hand looms. Indeed, in that way the most artistic work must still be done, and there is a revival of the use of the hand loom in our own day for the making of fine curtains, table linens, and tapestries. The most wonderful hand weaving is that done at the Gobelin Tapestry Works in Paris. This establishment was founded in the fifteenth century, and the same methods are still employed. Since the days of Louis XIV the Gobelin Works have been the property of the French government.

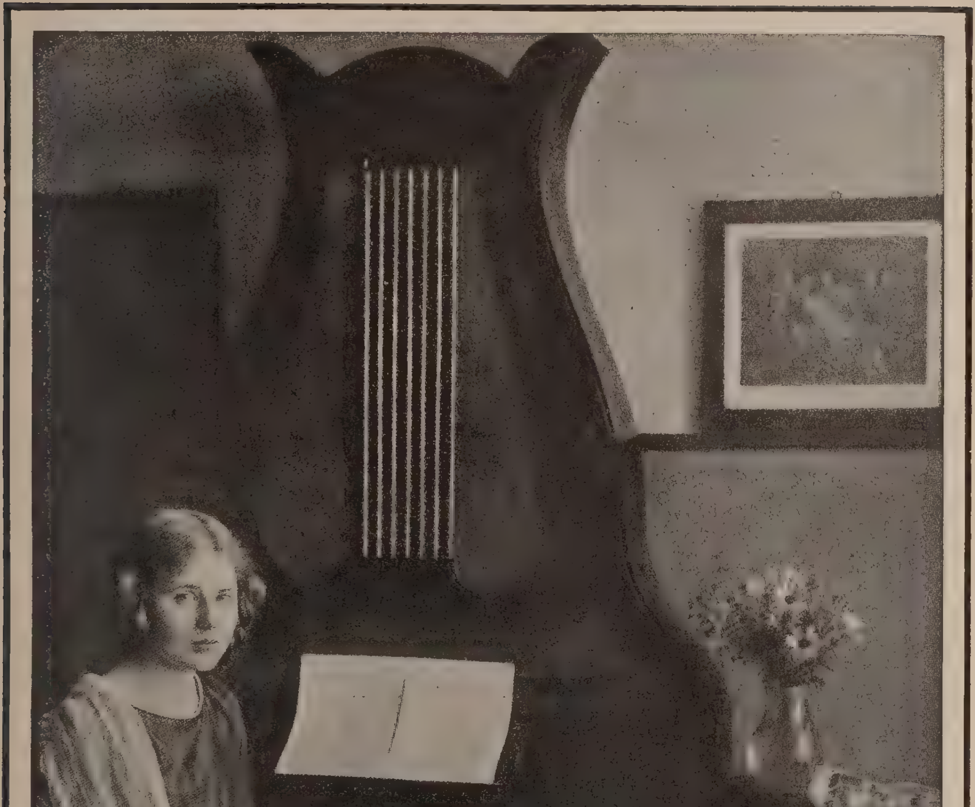
FORERUNNERS OF THE PIANO

The invention of the clavier, or keyboard, was the real beginning of the piano, although its first application was to the organ. Then came the clavichord, an instrument of stretched wires played by a keyboard, the first mention of which dates back to 1404. This was followed many years later by the harpsichord, so called from the shape of the sounding board, which was that of the harp, like a modern grand piano. A third instrument of the same class was the virginal. Upon these instruments some of the greatest of our classical music was composed, such as the great works of Sebastian Bach and not a little of the music of Mozart. Queen Elizabeth was a fine performer on the virginal, and its use became a fashionable accomplishment. Haydn and Beethoven were very partial to the clavichord. The spinet, of which you will often hear, was a small form of the harpsichord. These inventions all belong to the seventeenth century and reached their highest perfection about 1700. Clavichords are now made in small numbers for special purposes. The piano was invented by an Italian named Bartolomeo Cristofori, about the year 1720. He was a harpsichord manufacturer, and his improvement was so revolutionary that it was long before it was received with favor by musicians. The reason for this was, not that it was not an obvious improvement, but that it necessitated learning to play all over again, and this they were not willing to do for the sake of helping a new invention. Nevertheless, like all improvements, it was certain to come. Those who resist progress never succeed for long.

The essential difference between the pianoforte (as it was called, because it could be played "softly" or "loudly") and the instruments of the harpsichord type was that in all the earlier instruments the wires were picked, mechanically, and in the piano they were struck with a hammer. The improvement enabled the player to produce a far more powerful, rich, and varied tone, and at once lifted the instrument into a new rank.

TWO EARLY SCIENTISTS, FRANKLIN AND RUMFORD

Two names, both associated with colonial America, link the ancient with the modern ages of invention. Of Benjamin Franklin we have already spoken, as one of the pioneers of the printing press, and we shall have occasion to speak of him again, in telling about electrical inventions. But we may well give place here to a few words concerning Count Rumford.



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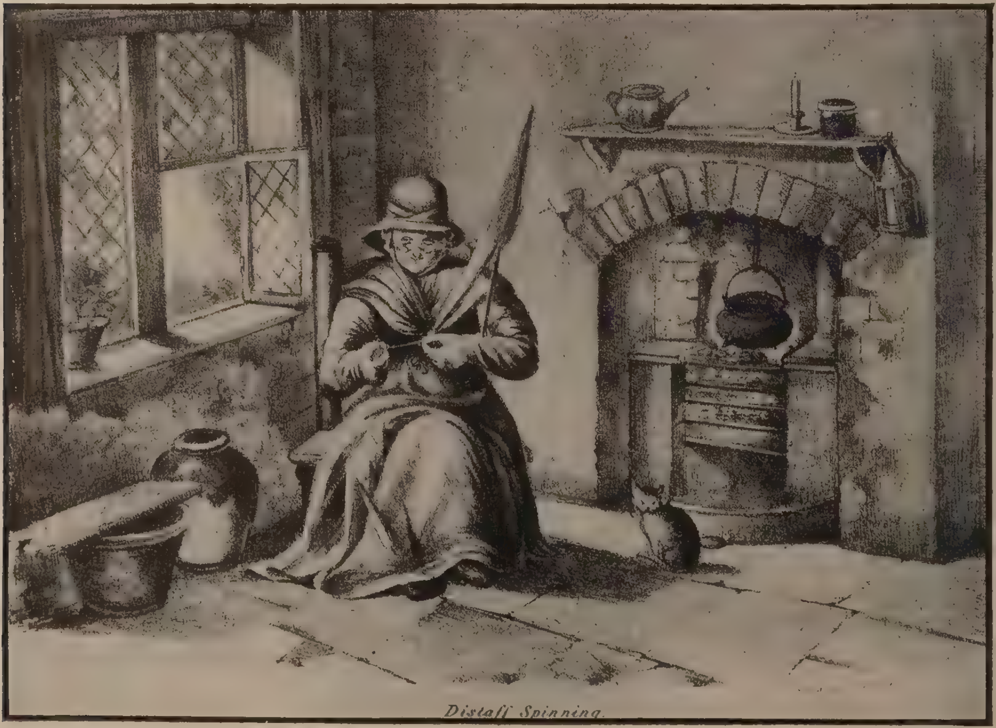
AN ANCIENT SPINET, THE FORERUNNER OF THE PIANO

His real name was Benjamin Thompson, and he was born in Woburn, Mass., in 1753. In the War of the Revolution he adhered to the English cause, and removed to England. His great mechanical genius and scientific attainments soon brought him substantial position, and he died wealthy, and honored by the title by which he is now known. He showed his affection for America by establishing the American Academy of Arts and Sciences, an institution that has done much for American science. Rumford's most practical invention was that of the stove. He observed the great waste of fuel in open-hearth combustion, and devised an inclosed stove with flues and drafts. This invention revolutionized domestic economy.

WHAT INVENTION MEANS TO US

The foundations of our present-day comfort and high standard of living were laid before the nineteenth century with the invention of printing, of the telescope, steam engine, gas lighting, balloon, weaving loom, cotton gin, etc. We are so used to seeing these in everyday use that we are inclined to take them for granted, giving little thought to the fact that without them we would still be living under the same conditions as were our ancestors a century or more ago. But for these products of man's brain and industry we would have no electric lights, no telephone or radio, no automobiles or railroads, no books or newspapers. Foods would be limited in variety, homes would be cold and poorly lighted, hours of labor would be long, and there would be little education or recreation.

In 1790, Congress established the United States Patent Office to protect inventors by giving them the exclusive right to their discoveries. This action by the government encouraged inventors to further efforts, and nearly two million patents have now been granted to inventors in this country alone, contributing greatly to our prosperity and well-being.



Distaff Spinning.

From "The Story of Textiles"

COMBING ROOM IN A WOOLEN MILL

The machine revolves and little metal combs smooth out the fibers.

THE INTRODUCTION OF MACHINERY

A CALENDAR of patents for the nineteenth century shows from one to ten important inventions for each of the one hundred years. It is as if we had been for a long, long time drifting in a stream so quiet that not a ripple broke its surface, when we suddenly felt the pull of a powerful current, a forward lurch and motion ever swifter and swifter. We have reached the Age of Machinery. Invention follows invention with bewildering rapidity. We must select; we cannot describe, we cannot even mention, all. What wonder is it, after such a revolution in man's way of doing things, that there is great restlessness, that relations between the employer and his employees are frequently strained, and that many readjustments are required!

HOW DOES A MACHINE DIFFER FROM A TOOL?

We call anything a tool which requires both the strength and skill of man for every motion performed with it. The moment an automatic feature is introduced into any device, however slight it may be, and a portion of the work is done by its own adjustments, we have a machine. A fork in the hands of a cook beating an egg is a tool, but a simple Dover egg beater is a machine. It transforms energy into a new direction and of itself supplies the adjustments necessary to do this. The most significant feature of such an article is that it reduces labor. Hence we have the popular, and not inaccurate, definition of a machine as a labor-saving device.

WHAT MAKES THE MACHINE GO?

The first principles of mechanical inventions were discovered by the men of very early times, of which we have no record other than the stone implements which they left behind. These principles were the first uses of the lever, the inclined plane, and friction. On these for a foundation have been built all the intricate inventions of our own day. No one knows the names of these first inventors; indeed, it is probable that many men, in various climes and in centuries wide apart, found out, each for himself, these principles and the application of them. Something like that is true even of our modern inventions. A hundred minds in different countries work upon the same problem, such as the invention of a telephone or an airship, and the solution seems to come to many of them at about the same time.

THE LEVER

No doubt many a small boy to-day learns through his own experience and experiments that the lever may be used in many ways, just as some primitive ancestor did, without making a particular study of the reasons why. Yet such a particular study was made more than two thousand years ago by the famous Syracusan, Archimedes, whose remark, "Give me but a fulcrum [place] to rest my lever upon and I could move the world," has been repeated millions of times by those who had slight idea of the laws of the lever or the meaning of the statement. The action of the lever may be illustrated by a pair of scissors, a wheelbarrow, or a pair of tongs, but there is only one law — that a large weight may be moved through a small distance by a small weight moving through a proportionally greater distance. For example, if one arm of the lever is ten times as long as the other, the power of one pound will lift a ten-pound weight. By the same principle, if you could make a lever the long arm of which should be millions enough of miles in length, one man could exert force enough to balance the earth, just as Archimedes said.

It is a not uncommon sight to see men hoisting a safe to an upper window in one of our city blocks. Watch them and you will see a modified form of lever. One or two men will wind a windlass, and the safe will rise slowly in the air. The men themselves could not for a moment lift it, but they can hoist it with the help of the pulley. Archimedes knew all about this, and was regarded as something more than human because he set up a system of pulleys that made it possible for him, sitting on the shore, to draw a heavy galley from the water. A windlass is a cylinder turning on an axle propelled by a long handle, a rope being wound about the cylinder. The axle is the fulcrum; the pull on the rope, the weight. The same law of the lever acts in the case of toothed or cogged wheels, or wheels of different sizes placed at a distance apart and connected by a belt, which may also lengthen the lever arm. It is wonderful in what a variety of ways this principle of power can be applied. The modern derrick or crane is a fine illustration that may be seen where any large building is in course of construction. In the excavation work on the Panama Canal the steel steam scoops were among the wonders of mechanism, moving as though animated with a human intelligence but with more than human precision and power. Take the first chance you can get to watch a steam scoop or a steam dredge in the river or harbor; and then remember that this massive machine, with its steel beams and chains and great scoop with hinged bottom, works on the same simple principles of the lever that Archimedes discovered.

THE INCLINED PLANE

Suppose it is necessary for one man to raise a barrel of sugar weighing three hundred pounds through a distance of four feet. It is practically impossible for him to do this work by main strength, but by arranging a plank twelve or fifteen feet long, so that one end rests against the upper level and the other against the lower level, the barrel may be rolled up this inclined plane with very little difficulty.

The ax is probably the oldest example of the inclined plane, though combined with a cutting edge. It is found in the Rough Stone Age and in all ages since, from the earliest stone ax to the latest blade of tempered steel and well-balanced handle. This is the principle of the wedge. The principle is of very ancient use, and was employed in building the great pyramids of Egypt. In modern machinery it is most used in the wedge and the screw, the latter being simply an inclined plane adjusted spirally about a cylinder. You may not have thought of a knife blade as a very thin wedge, but so it is, and every time you cut with it you are using the principle of the inclined plane, just as you are when you use a hatchet or an ax, which is said to have played as large a part in human industry as any single implement. The saw is an equally familiar illustration. Think of each tooth as an inclined plane, combined with a cutting edge, and you will see the law of its working.

FRICTION

The third principle, friction, or the rubbing of one surface upon another, means loss of power, and gives the inventor trouble when he is trying to invent a powerful and smooth-running machine. Yet without it machinery would be useless. It is friction that makes the belt turn the wheel, that makes the car wheel move on the track, that makes movement of any kind possible. Friction is due to the fact that all surfaces, no matter how smooth they look or how carefully polished they are, contain roughnesses or granulations which often can only be seen under the microscope. If this were not true of all materials with which we have to deal, we could not walk

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STEAM SHOVELS, PANAMA CANAL

These shovels or "scoops" offer good illustrations of the principle of the lever.

or hold anything in our hands. This world would be too slippery a place for us. Friction is necessary, and the thing is not to have too much of it either in machinery or society. Friction depends upon the actual contact or rubbing of the roughened surfaces upon each other. It is much greater where the two substances slide over each other than where one rolls upon the other. The wheel is the primitive reducer of friction, and is in constant use to lessen loss of power. The best man could do before he discovered the use of the wheel turning on a hub was to carry his heavy loads on his shoulders or drag them along the ground on a pair of poles or runners. But the wheel vastly reduces the friction between a weight and the earth and makes it possible for a man to draw a load far beyond his power to drag or carry.

In modern machinery, power losses through friction are further reduced by the use of ball or roller bearings. Here again we find an application of the "wheel" idea, small balls or rollers of steel being introduced to prevent the rubbing of one metal surface on another. Friction, one of the principles which have made machinery possible, is also, strangely enough, machinery's greatest enemy. It not only wastes power, but will destroy the machines themselves if its effects are not guarded against. That is why so much care is given to lubrication, which is merely a means of reducing friction by the use of oil or grease on moving parts. The wheelbarrow, the lawn mower, or the wheels of wagons squeak and complain if not properly greased or oiled. If these slow-moving mechanisms show such evident effects of friction, it is far more important that gasoline engines and other high speed machines have proper provision made for ample and effective lubrication.

THE INTRODUCTION OF MACHINERY

In 1764 Hargreaves, an Englishman, invented the spinning jenny, by which at first eight threads were spun at once, but this number was rapidly increased until the then surprising number of eighty were operated at one time. The spinning jenny did wonderful work in its day, but the woolen yarn and flax thread thus spun of old were coarse and uneven of texture. Originally wool and flax were carded; that is, combed by hand so that the fibers might be loose and lie parallel. But soon a carding machine was invented by which the wool, flax, or cotton fiber passed over toothed rollers which did the same work far more rapidly and evenly, gathering the fibers together into a loose, untwisted column called a "sliver." The operator then drew out the sliver into a thinner form having a slight twist, called a "roving," and this went to the spinning jenny. But a better way of treating the wool and flax was invented by Arkwright soon after the spinning jenny came into use, by which the rovings were drawn through rollers, one pair after another, and the thread made much firmer and finer. Again this machine, which was called a "throstle," was improved by the "mule jenny," which has a traveling frame in which spindles are set. This frame draws out and twists the thread as it leaves the rollers of the throstle, then moves back again, winding up the thread on the spindles as it moves, then goes through the first operation again. Crompton invented the mule jenny, and, by means of it, for the first time thread of great fineness was made.

Modern machines combine the operations of carding, roving, and spinning, and so well do they work that yarn has been made for the purpose of testing machinery, of such slenderness that a pound of it would reach 4770 miles. Thus the spinning, which during all earlier ages of the world was done by the women of the household sitting by the fireside, became a factory operation in which thousands of operatives stand side by side watching the machines but taking no part in the work other than to mend a broken thread or supply fresh material for the whirling wheels.

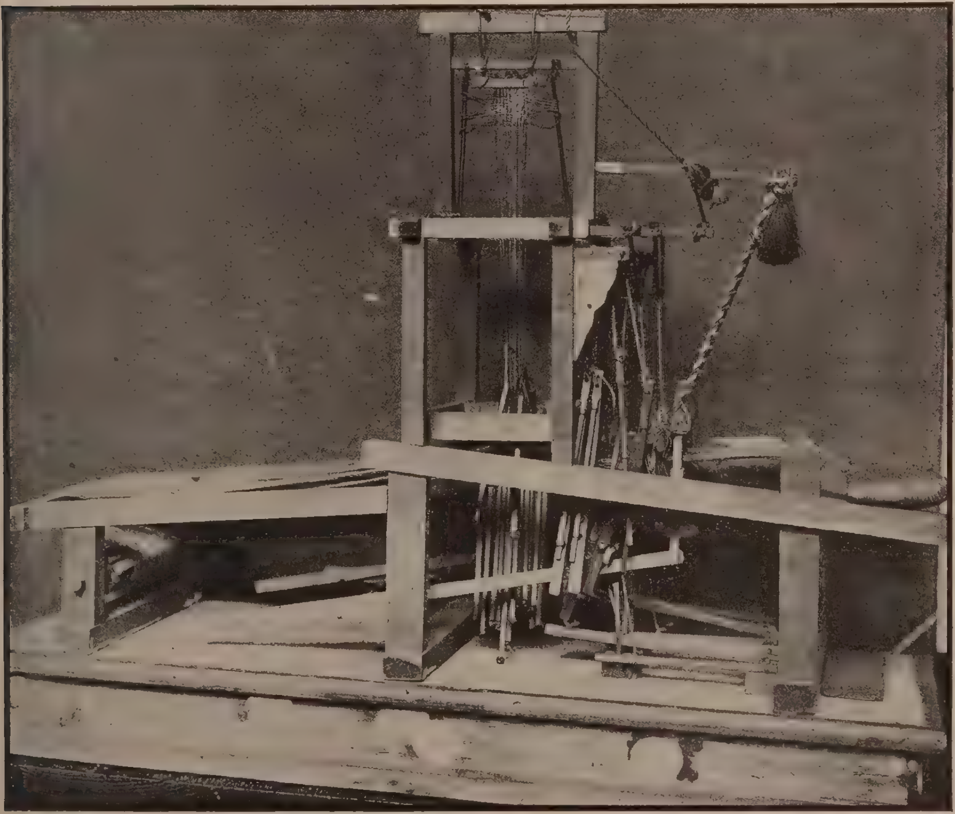
THE EVOLUTION OF THE LOOM

Weaving is perhaps the most ancient form of manufacture. In its simplest form it consists of interlacing threads or yarns to make a fabric. The most primitive people weave rushes in this fashion into mats, and even tribes otherwise considered savage weave coarse blankets in primitive fashion. The loom itself was an invention of the very earliest civilization. Among the Greeks, Minerva, goddess of wisdom, was famed for her skill in weaving. The story goes that Arachne, a Greek maiden, who was also skilled in weaving and embroidery, dared contest with her. Minerva admired Arachne's work, but was offended at the impiety of the subjects of her embroidery. So she changed the Greek maiden into a spider, and in this form, wrinkled and ugly because of the displeasure of the goddess, she yet continues to do most wonderful weaving.

Thus, so long ago were there hand looms that no one knows who invented them. They continued to be used through the ages, but little modified in form, until in 1787 one Dr. Cartwright, without ever having seen a loom before, constructed one to work by machine power. In its simplest form the loom is still worked by hand in many countries, and wonderful fabrics, such as Indian shawls, Turkish rugs, and the like, are produced that rival the most intricate work of the power loom. But for all that, the bulk of the world's weaving is now done by power.

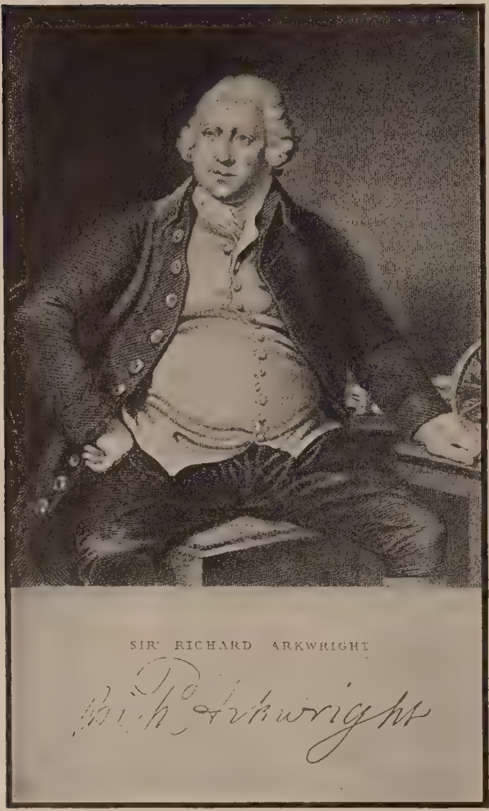
HOW THE LOOM WORKS

In a hand loom parallel threads are stretched from a roller which is called the "beam," or "yarn roll," to another which is called the "cloth beam." The threads thus stretched are called the "warp." An arrangement lifts alternate threads near the cloth beam and holds the upper and lower threads separate while the shuttle,



AN OLD HAND LOOM

From a model in the Peabody Museum, Salem, Mass.



From "The Story of Textiles"

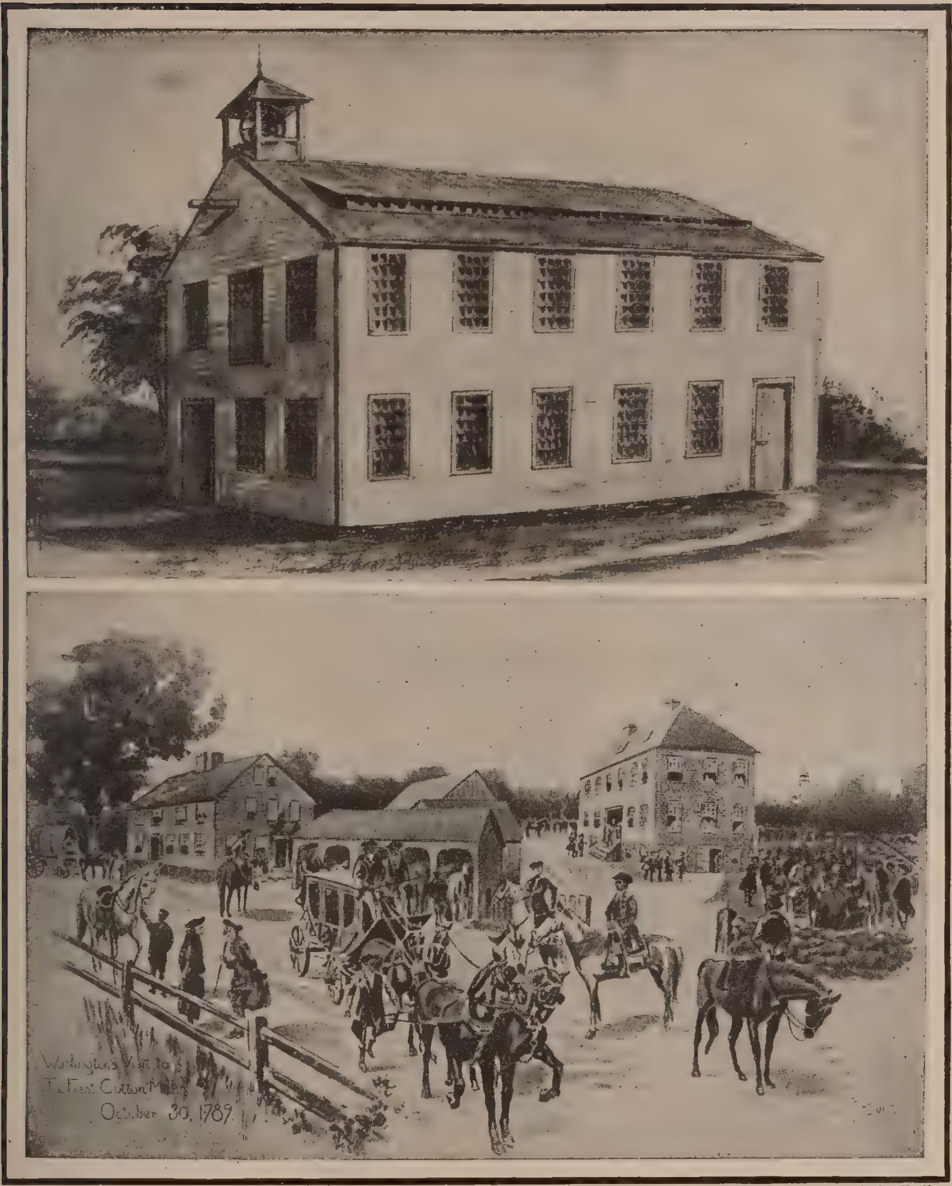
Sir Richard Arkwright was the inventor of the roller spinner or water frame and founder of the first cotton mill in the world, at Nottingham, England.

containing a thread of the weft, is thrown through. This space through which the shuttle is thrown is called the "shed." Then the mechanical arrangement lowers the upper threads and brings those below up into their place. The shuttle then shoots back and carries the thread through the shed again, and the reeds, wires which go up and down through the warp, press the woven threads tightly together. The reeds and the shuttle are moved by the weaver's hands, the warp threads are shifted up and down by moving the feet. Thus the weaver sits at the loom, tossing the shuttle, kicking the treadle, and watching the fabric grow before his eyes. As the work progresses the warp unwinds from the warp beam and the cloth winds up on the cloth beam. Such is the work of the primitive hand loom which has been in use since long before the dawn of history. Its principles are exactly those of the latest and most complicated machinery, though they have been modified and improved by a thousand modern inventions.

Arkwright's first mill at Nottingham, England, was driven by horses, but this species of motive power was soon found to be too expensive. In 1790 he entered into a partnership with Mr. Jedediah Strutt, and they erected a mill at Cromford, on the Derwent, and operated it by water power. This was the first cotton mill in the world to be driven by a water wheel, and from this circumstance the spinning machines were called "water frames." The yarn made in this mill, which was, indeed, the first wholly successful one, was very much more even, firm, and hard than that previously made by the spinning jenny. In 1793 the firm began to make calico wholly of cotton, and this was the first cloth manufactured in England entirely of this material, linen always having previously been used for the warp. In spite of much litigation and jealous opposition and usurpation of his rights, Arkwright's success was wonderful, and he grew immensely wealthy. He was the father of the "factory system," and was also the first to apply steam power to the operation of factory machinery.

THE SITUATION IN 1790

Thus, in 1790, we find England the foremost manufacturer of yarns in the world, the inventor of the carding machines, the spinning jenny, the roller spinning machine, and the fly shuttle in the weaving looms. Her business men were alive to the opportunities before them and perfectly aware of the possibilities of the textile business. The British government had passed laws protecting "home industries" and forbade the exportation of any machine or pattern of any machine recently invented which might "then or thereafter be used in the woolen, cotton, or silk manufacture of the kingdom, or goods wherein wool, cotton, or silk were used, or any model or plan thereof." This law was rigidly enforced. The United States was recognized as an open port by England only for the


Washington's Visit to
The First Cotton Mill
October 30, 1789

From "The Story of Textiles"

TOP: THE OLD SLATER MILL, PAWTUCKET, R. I., BUILT IN 1793. HERE THE FIRST COTTON SPINNING BY ARKWRIGHT MACHINES WAS DONE IN AMERICA. BOTTOM: WASHINGTON'S VISIT TO THE FIRST COTTON MILL AT BEVERLY, MASS., OCTOBER 30, 1789

SPOOLING ROOM IN A WOOLEN MILL

The revolving spools prepare the threads for weaving.

sale of English manufactures, and England was open to American raw textile material.

But this condition was not long to continue. American inventors and capitalists were hard at work trying to solve the problem of the application of machinery to the textile industry. The farmers of the North and the planters of the South needed a home market for their wool, flax, and cotton, and capital needed that avenue for commerce.

In Massachusetts the Hon. Hugh Orr, in Bridgewater, financially assisted the Barr brothers in constructing a spinning jenny, stock card, and roving machine. In 1785 he helped Thomas Somers in building a machine similar to the Arkwright water frame, which became known as the "States Model," but was not sufficiently perfect to be practical. In 1787 a cotton factory of several jennies was started on the Bass River, in Beverly, Mass., and an attempt was made there and in Providence to operate a spinning mill at a profit. These, too, were failures, and Moses Brown of Providence bought the machinery. Mr. Brown was a student and financier who believed that sometime the great Arkwright secret must be discovered by American inventors, and he bought all discarded models with the hope that some useful principle involved might be saved. Mr. Brown had a deep interest in commerce and manufacturing, but in 1790 had practically retired, leaving large interests to his kinsman and son-in-law, Almy and Brown. This firm operated several branches of the textile business, among them a fulling mill, which stood where the southwest abutment of the Pawtucket bridge now stands, and in which most of the unsuccessful spinning machinery bought by Mr. Brown was stored.

STEAM DRILLS IN PANAMA CANAL WORK

STEAM

IT is hard to think of machinery without power. Had it not been for the steam engine, we may well doubt if the Age of Machinery would have come to free the slave and enrich the world. But when Hargreaves and Arkwright brought out their spinning and weaving machines, the power to run them had already been developed by the ingenuity of James Watt. Watt secured his patent in 1769, but, strangely enough, there was little thought of using his engines to run machinery. The steam pump, the locomotive, and even the steamboat preceded the use of steam power for manufacturing. Nevertheless, the idea was there, and it is to the ingenious Scotch boy that the world is indebted for it. He it was who changed a philosopher's toy into a useful engine.

THE INVENTOR OF THE STEAM ENGINE

James Watt was born at Greenock, Scotland, January 19, 1736. He was a very delicate boy, so feeble that he did not go to school regularly like other children. His mother taught him to read, and his father gave him lessons in writing and arithmetic. He was confined to his room a good deal of the time, and there he occupied himself by playing or studying, just as he pleased. One day a friend called and saw the boy stretched out on the floor, drawing all sorts of lines upon it with a piece of chalk. "Why do you let that boy waste his time so?" said the neighbor. "Why don't you send him to school where he will learn something useful?" Mr. Watt replied: "You may find, sir, that you are mistaken; before you blame me, examine attentively what my son is about." Upon closer inspection, it was found that this feeble boy of six years old was working on a problem of geometry.

The father soon found that his little son had a natural mechanical talent, and so gave him some tools. With these he took to pieces and put together all the children's toys he could get hold of, and was all the time making new ones. He built a small electrical machine which gave out brilliant sparks, to the amusement and astonishment of the neighbors. It was plain to all that this was no common child.

One evening, as the lad was sitting at the tea table with his aunt, Mrs. Muirhead, she said to him: "James Watt, I never saw such an idle boy; take a book or employ yourself usefully. For the last hour you have not spoken one word, but taken off the lid of that kettle and put it on again, holding now a cup and now a silver spoon over the steam, watching how it rises from that spout, and catching and connecting the drops it falls into. Are n't you ashamed of spending your time in this way?" There are different ways of looking at this story; some have thought the boy's mind was even then working out the principle of the steam engine, others look upon it as simply the amusement of an idle hour. When we remember what kind of boy this was, and what he became, we are safe in believing that this young mechanical genius was beginning to think about the power and possibilities of steam. When someone asked Sir Isaac Newton how he had discovered the attraction of gravitation, he replied: "By continually thinking about it." That is the way all great inventions come about, and doubtless this was the case with James Watt.

But ill health often kept him at home, and at such times he devoted himself to the study of chemistry and physics. At last, when nineteen, he went to London and put himself under John Morgan, a mathematical and nautical instrument maker. With his own hands he made these delicate instruments, so unlike the huge engines which were afterward to bear his name. After about a year, young Watt returned to Glasgow, but the corporations of arts and trades refused him the privilege of opening even the most modest shop. The University of Glasgow came to his aid and gave him a room in one of their buildings, as well as the title of mathematical instrument maker to the university.

This connection with the university was a most happy thing for young Watt, just turning his twenty-first year. It brought him into close association with some of the ablest scientists of his day, and made them his friends as well as patrons.

The actual accomplishment that entitles James Watt to his fame was not the discovery of the expansive force of steam, nor even the construction of the first instrument for utilizing that force. Hero of Alexandria, in Egypt, knew about this force more than a hundred years before Christ, and describes an application of it to produce a rotary motion. In 1630 a French writer described a method of raising water to the upper part of a house by means of steam. In 1655 the Marquis of Worcester published a book called the "Century of Inventions," in which he set forth a similar method. In 1698 a patent was granted to Captain Savery for a primitive method of utilizing the power of steam. About the same time M. Papin tried to construct a steam engine. In 1705 Newcomen and Cawley constructed a machine for pumping, with a detached boiler in which steam was generated. One of those Newcomen engines was in the laboratory of the University of Glasgow, and young Watt was set to work repairing it. He improved its construction and made it work successfully, so that it was used in the classrooms for the instruction of the students. But it was a very incomplete affair and not capable of doing any serious work. What James Watt really did was to construct a steam engine that was practical for the great purposes to which it was soon put. He added new parts to the incomplete engine. He added a condenser, with an air pump, and also a steam jacket to keep up the necessary heat in the cylinder. He made a steam engine that would do the work of the world and that advanced civilization more than anything else had done since the invention of printing.

Fifteen years after Watt had perfected his engine, Robert Fulton's little steamboat made its trial trip on the Seine River in France. Within twenty years Fulton used one of Watt's engines in running the *Clermont* from Albany to New York in thirty-six hours. The opening up of the coal mines had developed a crying need for some new motive power, and Watt was soon kept busy in setting up his engines in the collieries.

James Watt was fortunate in being born at the right time. The world was ready for the inventions which his genius conceived and executed. Three years after Watt had made his first improvements on the pumping machine, Dr. Erasmus Darwin, the grandfather of Charles Darwin, wrote "The Botanic Garden," in which is found this prophecy:

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge or drive the rapid car.
> Or on wide waving wings, expanded, bear
> The flying chariot through the fields of air."

The world was ripe for this great invention, and James Watt was the man with the skill and genius and industry to perfect it. The man and the occasion were at hand. That is the secret of all great accomplishment.

HOW DOES THE STEAM ENGINE WORK?

Water is really a wonderful substance. When cold it is a solid, ice. Heat it a little and it runs, a fluid. Heat it more and it becomes a vapor, expanding very much in so doing. This vapor is steam and it is full of energy. It pushes with great force when confined, trying to expand in all directions. Thus if it is confined in a cylinder and a piston is pushed down against it, it will push back at the piston with great force. If we thus let it drive the piston to the end of the cylinder and then let the steam out, but let other steam in behind the piston at the other end of the cylinder, it will push the piston back.

Something like this the boy James Watt thought out as he watched that kettle lid dance, and in doing it he had the basic principle of the first steam engines. A little water heated makes a great amount of steam, for the steam occupies sixteen hundred times the space the water did. Thus by confining water in a boiler and changing it to steam, we are able to produce high pressures, the average working pressure in a boiler being about 125 pounds per square inch.

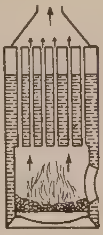
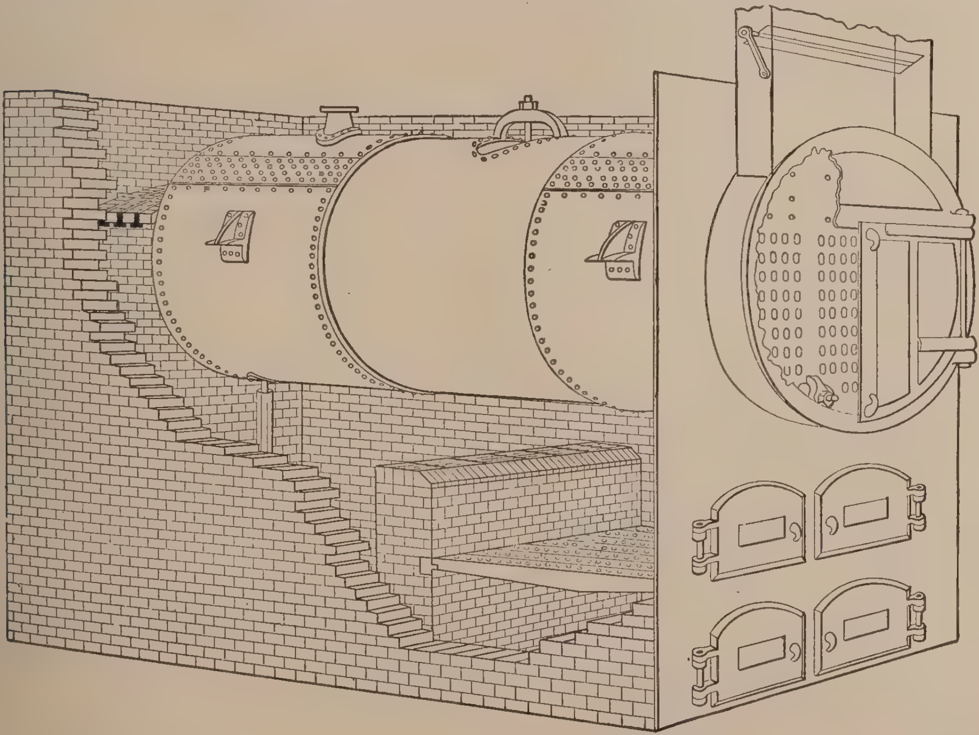


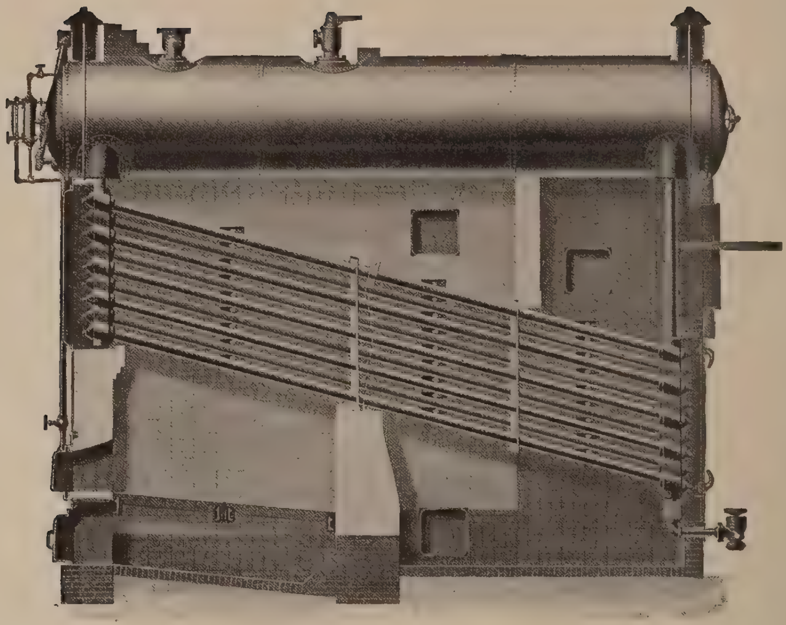
DIAGRAM OF A SMALL VERTICAL BOILER

Then if steam is admitted by way of small openings or ports, first into one end of a cylin-


From "Steam-Boilers," by courtesy of Edward F. Miller

A HORIZONTAL RETURN MULTITUBULAR BOILER

This is the kind of boiler generally used in mills and factories.



A WATER-TUBE BOILER

The advantage in this boiler lies in the fact that higher pressures may be used than in fire-tube boilers and that it makes steam more quickly.

der containing a piston and then into the other, it may be readily seen that this steam will drive the piston back and forth as long as the pressure is maintained. So steam engine operations begin in a boiler.

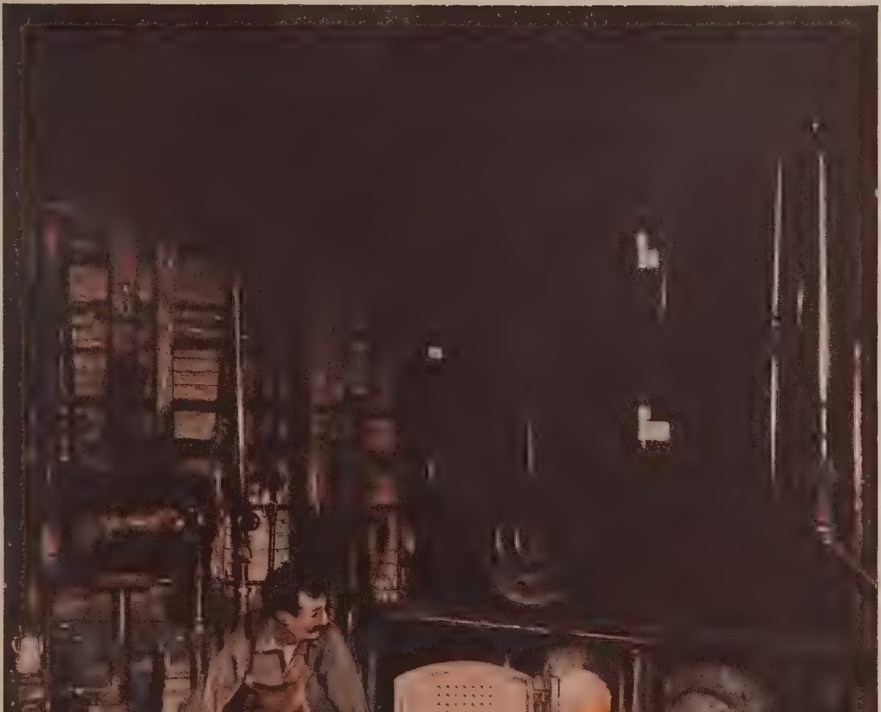
The first boilers were simply kettles, having the lid fastened on tight and with a pipe to take the steam to the engine cylinder. Such boilers, however, were slow to heat, and tubular boilers were constructed. These had many tubes passing through the water space, dividing it up and allowing the heat from the gases which passed through the tubes to come in contact with a much larger surface of water, and thus to heat it more quickly.

The most powerful locomotives have boilers containing as many as 350 tubes, which with the fire box give six thousand square feet of surface for the heat to act upon. The illustrations show the arrangement of the various parts of several types of boilers.

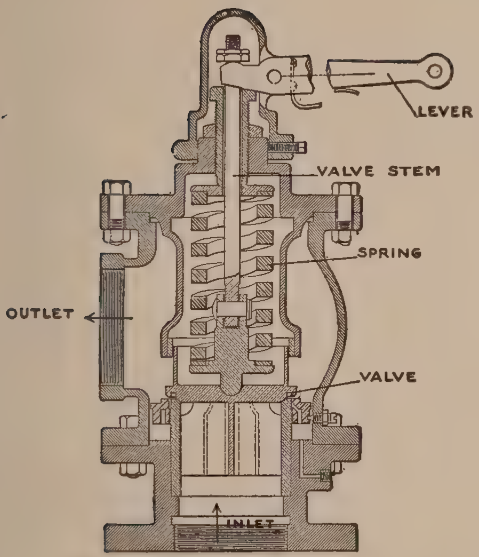
On page 25 is a diagram of a small vertical boiler such as is used with donkey engines where excavations are being made and buildings erected. It has vertical fire tubes. The furnace is surrounded by water and coal is fed through a door on the side.

The lower illustration on the same page shows a horizontal return multitubular boiler in its setting of brickwork. The fire is built on the grate under the boiler, and the hot gases pass over the bridge wall at the back of the grate and, entering the fire tubes of the boiler at the rear, move forward to the front end, where they pass through the flue to the chimney. This type of boiler is much used for pressures below 150 pounds and where the amount of steam taken from the boiler does not vary, as in mills and factories.

Above is a water-tube boiler. These boilers are not so dangerous as the one just described, as most of the water is confined in small tubes which, if one should give way, would not do very serious damage. For this same reason higher pressures may be used, the greatest being about 250 pounds. The water circulation in



IN A BOILER ROOM



From "Steam-Boilers," by courtesy of Edward F. Miller

THE SAFETY VALVE

When the pressure in a boiler rises nearly to the danger point, the valve is forced open and steam escapes.

these boilers is much better than in fire-tube boilers, and they will, therefore, make steam much more quickly.

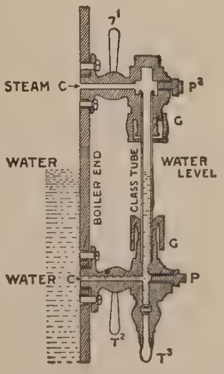
If we take bellows and send air rushing up through an open fire, it will burn much more rapidly. If a similar thing is done with the fire of a steam boiler, it is called "forced draft." The fires beneath the boilers are so arranged that air under pressure is forced up through them and has no other way to escape than by passing through to the chimney. This makes the combustion very rapid and greatly increases the heat and the resultant amount of steam. Forced draft is used on naval vessels and other fast boats. It is also used in many stationary power plants. Oftentimes by using forced draft a cheaper grade of coal may be burned and much money saved.

The most important fittings on a boiler are the safety valve, the water gauge, the steam gauge, and the mechanism for feeding the boiler with water.

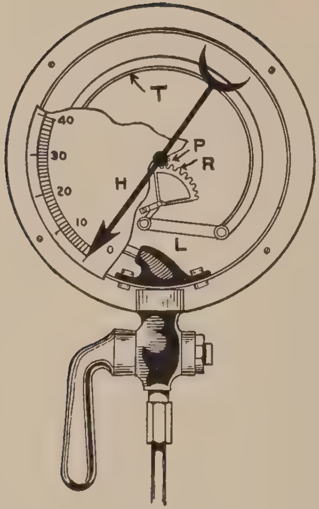
Steam is a good servant but a terrible master, and must always be kept under control. If the steam pressure within a boiler becomes too great, it must either be allowed to escape or the boiler will burst, with terribly disastrous results. Steam thus confined is as dangerous as gunpowder. Hence every boiler has a safety valve. This is a valve or cover which fits tightly over an opening in the top of a boiler where the steam is stored. This cover is held in place by a heavy spiral spring which may be so regulated that the valve will open at any desired pressure. This pressure is usually five or ten pounds above the working pressure, but well below the danger point. The safety valve must open wide enough to discharge all the steam that the boiler is capable of making. It remains open until the pressure drops three or four pounds below the blowing point and then closes suddenly. After a safety valve is set to blow at the proper pressure, it is locked, usually by the boiler insurance company, so that it cannot be tampered with. By means of a lever on the top, the valve may be opened by hand. This is done at least once a day, to be sure that the valve is not sticking on the seat. Such a valve is shown here, with the various parts indicated.

The water gauge, or water column as it is usually called, consists of an upright glass tube so connected at each end with the boiler that the level of the water therein will be shown in the tube. This tube must, of course, be able to stand the same steam pressure as that in the boiler, and is therefore made of very heavy special glass.

The steam gauge in a different way shows the amount of steam pressure at any given time, an arrow registering it on a dial, as may be seen in the illustration (page 28). Pressure within an elastic tube always tends to straighten it. So such a tube, bent within the dial, straightens with the pressure and swings the arrow a distance proportional to the pressure. The safety valve works automatically and does not need the attention of the fireman; the steam



A WATER GAUGE



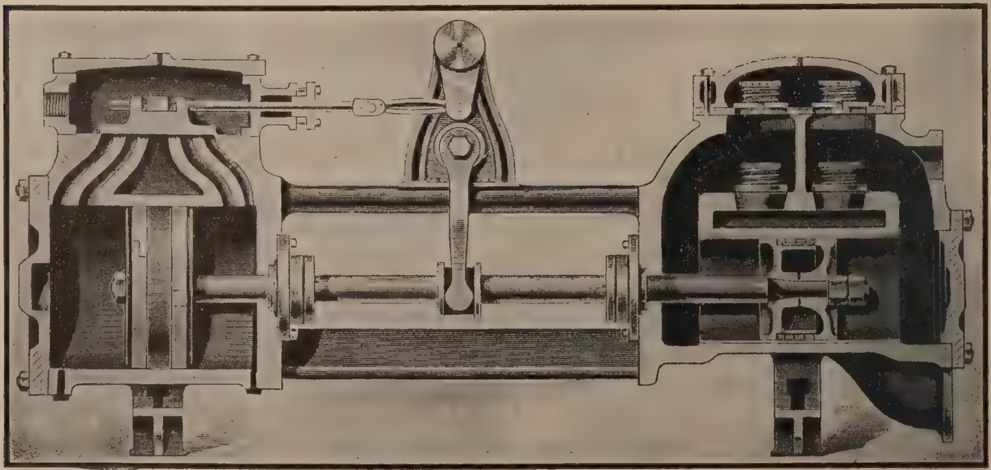
THE STEAM GAUGE

gauge and water column, however, require constant watching to keep the boiler working within its safe limits of steam pressure and water level.

When a boiler is supplying steam for any purpose at all, an amount of water equal to the steam used must be pumped into the boiler to keep the water level at the proper height. This is generally done by a boiler feed pump, of which there are many types; some are driven directly by steam, some by electric motors, and some, in small plants, by the main engine. The principal parts of a direct-acting steam pump for feeding boilers are shown below. The steam cylinder with its piston, and valve gear for admitting and discharging the steam, is seen at the left. At the right is the water cylinder with its plunger or piston attached to the opposite end of the rod that moves the steam piston. The pump valves, four of which are shown, are disks held on their seats by springs and usually made of rubber. The two lower are the suction valves, and the two upper are the discharge valves. Both cylinders, as may be seen, do work at both ends; that is, they are double acting.

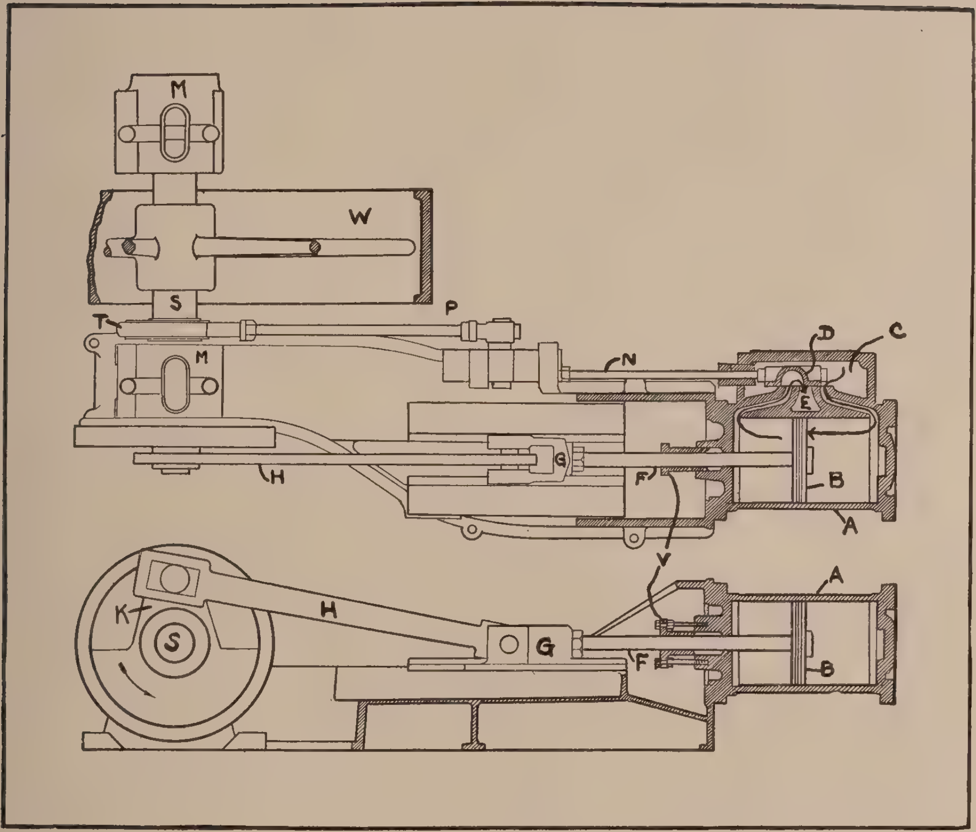
It will be noticed that this steam pump has no flywheel because it is often necessary to run at a much slower speed than would be possible if a flywheel were used. As there is no flywheel to steady the action of the pump, a great deal of steam must be used to make it run properly.

Thus we have within the boiler this giant steam pushing with all his might to get out, eager to rush through any valves or pipes to get his freedom. The steam engine converts this pent-up energy into action, forcing the giant continually to push the piston out of his way, thus working for his freedom. There are two kinds of steam engines: the reciprocating, employing cylinders and cranks, and the rotary or turbine engines. The reciprocating engine is the sort of which Watt dreamed as he



A DIRECT-ACTING STEAM PUMP FOR FEEDING BOILERS

At the left is the steam cylinder with its piston, at the right the water cylinder and its plunger.



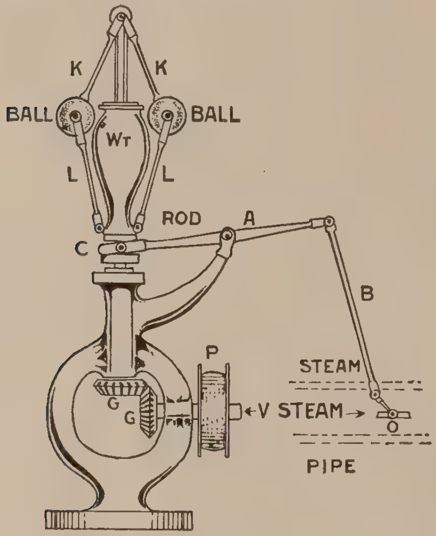
PRINCIPAL PARTS OF A SIMPLE STEAM ENGINE

Above is given the plan; below, the elevation.

watched that kettle lid dance, and the one to this day most commonly used.

Above are shown the principal parts of a simple steam engine. The upper view is a plan and the lower an elevation; only part of the flywheel, *W*, is shown in the plan and it is entirely omitted in the elevation. A section through the middle of the cylinder, *A*, is shown in both views.

Steam coming from the boiler enters the valve chest, *C*, in which the valve, *D*, moving back and forth, admits steam first to one end of the cylinder and then to the other, at the same time connecting the opposite end with the exhaust pipe, so that the steam may pass out of the cylinders after it has done its work. The drawing shows the steam entering the right-hand end of the cylinder and pushing the piston, *B*, toward the left, while steam in the left-hand end of the cylinder is being pushed by the piston out into the exhaust passage, *E*. The movement of the piston, *B*, is carried by the piston rod, *F*, to the crosshead, *G*, which slides to and fro on suitable guides. This sliding motion of the crosshead is then changed by means of the connecting rod, *H*, into the turning motion of the crank, *K*. This is fastened to the main shaft, *S*, which turns the flywheel and from which the useful work of the engine is obtained. *MM* are two bearings which support the main shaft. The motion of the valve is obtained from the eccentric, *T*, through the eccentric rod, *P*, and the valve rod, *N*. An eccentric is a mechanism doing the same work as a crank and producing a very small sliding motion. *V* is a stuffing box, which is an arrangement to keep the cylinder steam tight and yet to allow the piston rod to slide back and forth through one end.



THE "THROTTLING" GOVERNOR, INVENTED BY WATT

Now used only on small engines.

THE GOVERNOR

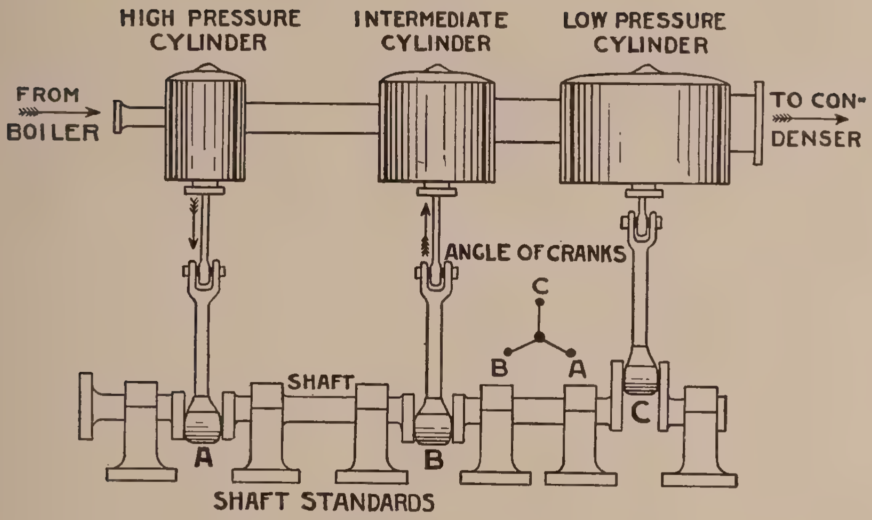
The governor is a very important part of most engines. The work which many engines do is continually varying in quantity. For instance, with an engine driving a machine shop, the different machines are constantly starting and stopping, so that at one instant the engine may be delivering fifty horse power and a moment later forty horse power. Now the speed of the engine must be the same, no matter how much the work varies. The governor is what makes this possible, and all except small, unimportant engines are so equipped.

Governing is usually done in one of two ways, either by varying the pressure and quantity of the steam or, keeping the pressure constant, by varying the quantity alone. An example of the first type, which is called the "throttling" governor, is shown above. A belt driven by a pulley on the main shaft turns a small pulley, *P*, at the foot of the governor. By this belt, motion is transmitted through two bevel wheels, *G G*, to a vertical shaft. From the top of this shaft hang two heavy balls on links, *K K*. By two more links, *L L*, the balls are connected with a weight, *Wt*, which has a deep groove around the bottom. When the shaft revolves, centrifugal force makes the balls fly outward and the weight, *Wt*, is drawn upward, drawing with it the fork *C* of the rod *A*, the ends of which engage with the groove. As *C* goes up, the other end of the rod is pushed down, and the rod *B* pushes down rod *O*, which is attached to the spindle operating a sort of shutter in the steam pipe. As a result, the steam is "throttled" more and more as the speed increases, until it has been so reduced that the engine slackens its rate and the balls fall, opening the valve again.

This form of governor was invented by James Watt. It is now used only on small engines, as it causes the engine to run with poor economy. Governors which vary the quantity of steam without varying the pressure are called "flywheel" governors, as they are usually attached to the flywheel. They act by balancing the centrifugal force of weights against the action of springs, and the weights are made to assume different positions for different engine speeds. The valve of the engine moves as the weights move, and thus the quantity of steam used is varied.

THE CONDENSER

When steam is exhausted from an engine into the atmosphere, it is thrown away. Now in many places, as on board ship, the supply of water which may be used in the boilers is limited, and none of it must be wasted. In such cases the steam leaving the engines, instead of passing uselessly into the air, is directed into a receptacle called a "condenser," where it is changed back to water, so that it may be used again in the boiler. Condensers where the steam and the cooling water are mixed together are called "jet" condensers. Where the exhaust steam and the cooling water are kept separate by having the water pass through tubes and the steam circulate within a closed shell around these tubes, the condenser is called a "surface"



TRIPLE-EXPANSION MARINE ENGINE

condenser. These latter are used on shipboard, where salt water may be used for cooling the steam which is made from fresh water.

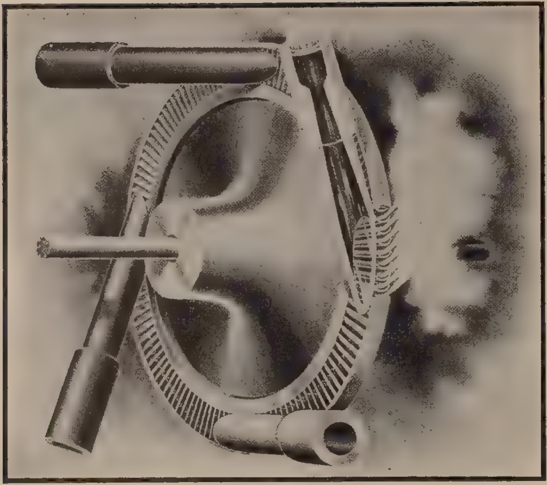
Besides saving the condensed steam for further use, the pump which pumps the condensed steam from the condenser, in so doing causes the pressure against which the engine is exhausting to be lowered to a point considerably below atmospheric pressure. This adds to the power and economy of the engine. The condenser was invented by James Watt.

COMPOUND ENGINES

In the early days of the steam engine the pressures used were low, not generally over fifty pounds. A single cylinder was all that was necessary to get as much work as was possible at such pressures. As the pressures increased, however, it was seen that much more work could be obtained from the same steam if the expansion were divided between two cylinders instead of all taking place in one. A compound engine was therefore designed with two cylinders, one called the "high-pressure" cylinder and the other the "low-pressure" cylinder, and the work was divided between the two. Steam from the boiler entered the high-pressure cylinder at a steam pressure which was usually from 125 to 150 pounds, and by expanding to a pressure somewhat above atmospheric, changed a part of the heat energy of the steam into work. Leaving this cylinder at a pressure of from twenty to forty pounds, the steam passed into the low-pressure cylinder, which was made much larger than the other, owing to the greater volume of the steam at low pressures, and there finished its expansion, being finally exhausted from this cylinder at a pressure much below atmospheric.

Later it was found that better economy could be obtained with large engines by dividing the expansion among three cylinders, and thus the triple-expansion engine appeared. The general arrangement of such an engine is shown in the illustration. Nearly all compound and triple-expansion engines exhaust into condensers.

As these engines increase in power and weight, new forces must be taken into account. Strains that in a small engine are too small to notice become sufficient, in these large engines, to break the machine. One of the most important problems of the designer of a great engine is to balance the momentum of the tons of moving parts. This is accomplished with such delicacy that an engine developing 10,000 horse power may move at high speed without noticeable vibration.



THE DE LAVAL TURBINE

The wheel reaches a speed of thirty thousand revolutions a minute.

THE STEAM TURBINE

Strange to say, our latest and most effective kind of steam engine was made in a crude and simple sort of way more than two thousand years ago by a man named Hero of Alexandria. His engine was a wheel driven by steam much in the same way that the water in a modern revolving jet lawn-sprinkler makes the jet revolve. "Action and reaction are equal and in opposite directions," says the axiom. That is, if you push against anything to push it away from you, you also push yourself away from the thing. So the jet in the sprinkler, pushing out against the air, pushes the sprinkler round.

That is the first principle of one type of water turbine. The water, pushing out of the wheel under pressure, pushes the wheel around. If you substitute steam for water you have a steam turbine, just as you have a water turbine when water is used.

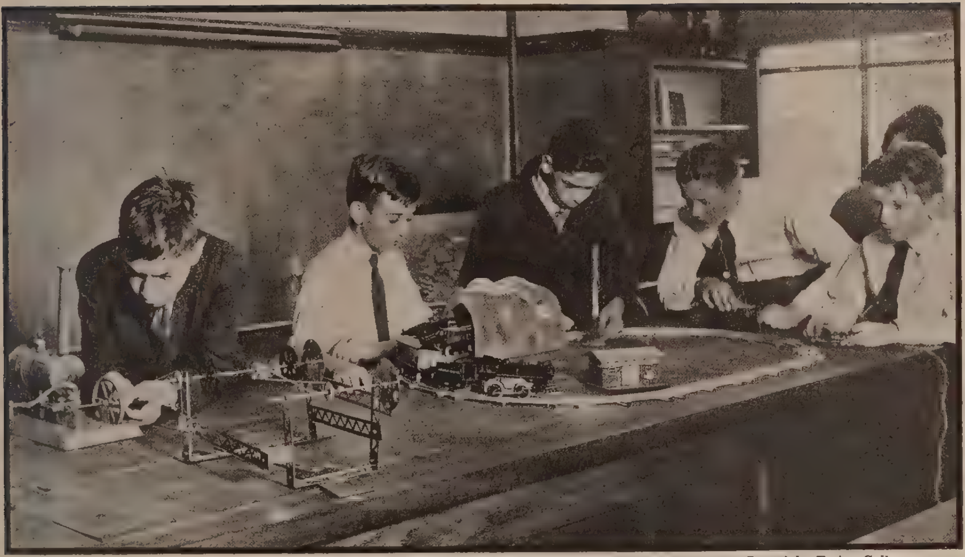
Steam, in expanding through a nozzle, has its heat energy changed into velocity energy; the pressure, of course, drops as the expansion takes place. In a turbine like the De Laval, the steam, therefore, leaves the nozzle at a very low pressure, but moves with a very high velocity. This will cause the wheel to revolve at a tremendous speed, which sometimes reaches thirty thousand revolutions per minute. This speed is, of course, far too high to be of any commercial value and is, therefore, reduced by gearing, so that the machinery driven, which is generally an electric generator or a high-speed centrifugal pump, revolves at about one tenth of the turbine's speed.

In other types of turbines it is arranged to change the heat energy into velocity by degrees, and so the speed of the turbine is kept within reasonable limits, it usually being from one thousand to four thousand revolutions per minute according to the size. This is done by having a large number of rows of vanes for the steam to act upon, instead of a single row as in the De Laval; it also has rows of blades fastened to the casing, arranged to alternate with the rows of moving blades on the rotor.

The expansion of the steam, instead of taking place in a nozzle, occurs in passing among these fixed and moving blades, and acting both by impulse and reaction delivers mechanical work to the shaft at a reasonable speed. The above is the principle of the Parsons turbine.

A sectional view of a Parsons turbine is shown on the opposite page. Steam enters at *S* and passes through the valve *V*, which regulates the speed under the control of the governor at the extreme right. The steam starts at boiler pressure on its journey through the fixed and moving blades at *A*, traveling toward the left. When it emerges from the last blades at *W*, it is at the lowest pressure which is maintained in the condenser to which it now passes. The movement of the steam toward the left will cause the whole rotating part to push in that direction. This push is balanced by the drums *P*, which are so placed that the steam can push just as hard against them in the opposite direction. A turbine of this type has a speed of about thirty-six hundred revolutions per minute.

Still another type combines the principles of the Parsons and the De Laval and divides the expansion into three or four stages, each stage having its own nozzles and a few rows of fixed and moving blades; the expansion, however,



Copyright, Ewing Galloway

A PRACTICAL USE FOR TOYS

Schoolboys learn about machinery by studying electric trains and engines.

all takes place in the nozzles, but by dividing it into several stages, the speed is kept within reasonable limits.

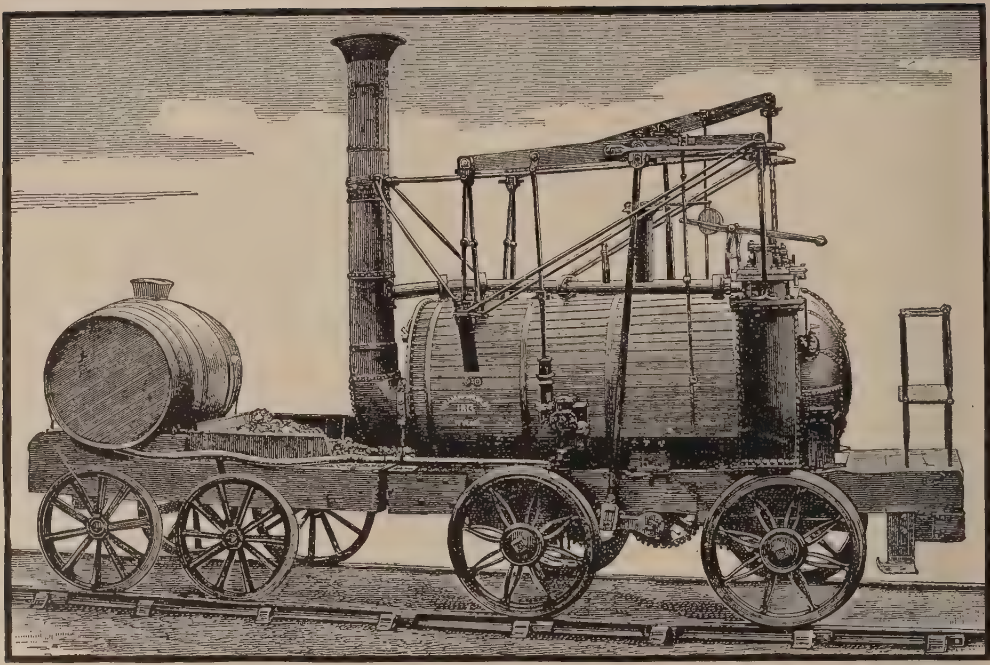
Turbine engines are of great use in swift naval vessels, as they are compact, run without vibration, and take up much less room than reciprocating engines. Many of the swiftest passenger steamships are now equipped with these small but mighty motors, which are so effective and take up so little space. The Parsons turbine is the one commonly used. On the turbines of the *Mauretania*, the great, swift Cunard liner, 1,500,000 vanes are used, and each low-pressure drum weighs 130 tons. The largest diameter of the drums is eleven feet eight inches. Reciprocating engines would take up many times this space.

The use of the turbine for ship propulsion is really a secondary matter compared with its installation in stationary power plants. It is replacing the reciprocating engine in many places, both as a main prime mover and as a means of driving the numerous auxiliary machinery. The fact that it is more easily tended, requires fewer repairs, and is more economical at high speeds, makes it especially adaptable to electric power stations, where it is now used almost exclusively. The turbine naturally runs at high speeds, but by introducing reduction gears between it and the driven machine it may serve as the power for slow-speed machinery, even being used to drive shafts through belting.

DEVELOPMENT OF THE LOCOMOTIVE

We are apt to think of the railroad as built for the use of the locomotive, and to-day that is strictly true. Yet there were railroads long before locomotives were invented. In 1630 such a road was in use in a coal mine in Newcastle, England, built of wooden rails on which cars were run by hand or horse power. Fifty years later a similar road was in use near the river Tyne, where one horse was able to draw four or five caldrons of coal at a load.

Iron rails took the place of the wooden ones about 1767, and ten years later someone conceived the idea of using single flanges for the wheels, the flange being placed on the out-



"PUFFING BILLY," 1813
An interesting forerunner of the modern steam horse.

side. The first cars with wheels having flanges on the inside, running on elevated rails, were built by William Jessop in 1789, and were so evidently superior that they were everywhere adopted. With minor changes this form of wheel and rail is in use to-day.

In 1802 Richard Trevithick of England produced a steam locomotive which hauled a wagonload of people over certain streets of London. But the roads were rough and the locomotive soon broke down. Two years later he designed another which was built for a coal-carrying railroad in South Wales, and there on several occasions it hauled ten tons of iron at a fair speed. But this machine was not considered a success financially and was abandoned. Other inventors produced cable roads and engines which ran upon cogged wheels, but none were successful until George Stephenson entered the field.

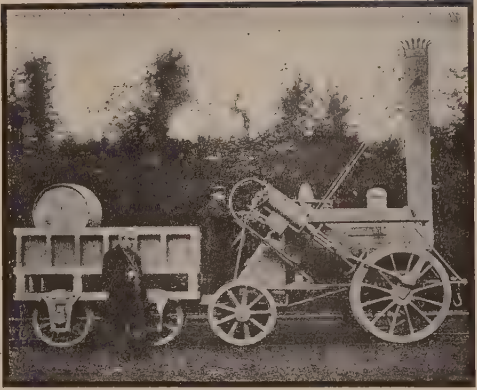
Stephenson was born in 1781, in great poverty, in a small colliery village. He was put to work when a child and could not write his name until he was eighteen years of age. But he was industrious and ambitious, and by the time he was of age was a skillful engineer. At twenty-six he was holding a position as engineer for a coal-mining company. In 1814 an engine which he built for them was placed on the colliery tramway. This engine showed many points of superiority over its predecessors, though it involved no new principles. It drew eight loaded wagons of thirty tons' weight, at a rate of four miles an hour, up a slight grade. But it would not keep up steam and the noise of its exhaust frightened all the horses in the neighborhood. The authorities ordered Stephenson to stop the engine or stop the noise, and in his endeavor to find a way to do the latter he discharged the exhaust into the smokestack, to muffle the sound. In this act he unwittingly solved the problem of the modern locomotive. Not only did the stack muffle the noise of the exhaust, but the force of the steam in it so increased the draft that double the amount of steam was generated. The chief obstacle in the way of success with the locomotive had been this failure to keep up steam, and the discovery made the path of future invention much easier. Stephenson built other locomotives, each an improvement, but the world knows him best by the success of the *Rocket*, built in his own establishment with the aid of his son Robert, and entered in a competition on the road between Liverpool and Manchester, at that time operated by cable.

A prize of $2500 was offered and the requirements were as follows:

1. The engine must effectually consume its own smoke.
2. The engine, of six tons' weight, must be able to draw, day by day, twenty tons' weight, including the tender and water tank, at ten miles an hour, with a pressure of steam upon the boiler not exceeding fifty pounds to the square inch.
3. The boiler must have two safety valves, neither of which must be fastened down, and one of them completely out of the control of the engineer.
4. The engine and boiler must be supported upon springs and rest on six wheels, the height of the whole not exceeding fifteen feet to the top of the chimney.
5. The engine with water must not weigh more than six tons, but an engine of less weight would be preferred, although drawing a proportionately less load behind it; if only four and one half tons it might be put on four wheels.
6. A mercurial gauge must be affixed to the machine, showing the steam pressure about forty-five pounds to the square inch.
7. The engine must be delivered, complete and ready for trial, at the Liverpool end of the railway, not later than October 1, 1820.
8. The price must not exceed £550 ($2750).

The first clause, requiring the engine to consume its own smoke, raised a problem that has not yet been satisfactorily solved. Still more of a stumblingblock was the speed requirement. Ten miles an hour seemed utterly absurd. One engineer stated publicly that "if it proved to be possible to make a locomotive go ten miles an hour, he would undertake to eat a stewed engine wheel for his breakfast." Nobody dreamed of what was to come in the way of sixty-mile-an-hour expresses.

Four firms entered the contest, and named their engines the *Novelty*, the *Sanspareil*, the *Perseverance*, and the *Rocket* — the last being the Stephenson engine. The *Rocket* won, with the *Novelty* a close second. The *Novelty* has been humorously described as looking like a "milk can set in the rear of a wagon, with a little smokestack in front like a dashboard." It carried fuel and water in the "wagon box" part of the frame, in front of the boiler. On its first trial it reached a speed of twenty-four miles an hour, running without any load. That engineer ought to have eaten the "stewed engine wheel" at once. The trouble with the *Novelty* was that it kept breaking down, behaving far worse than any automobile in that respect.

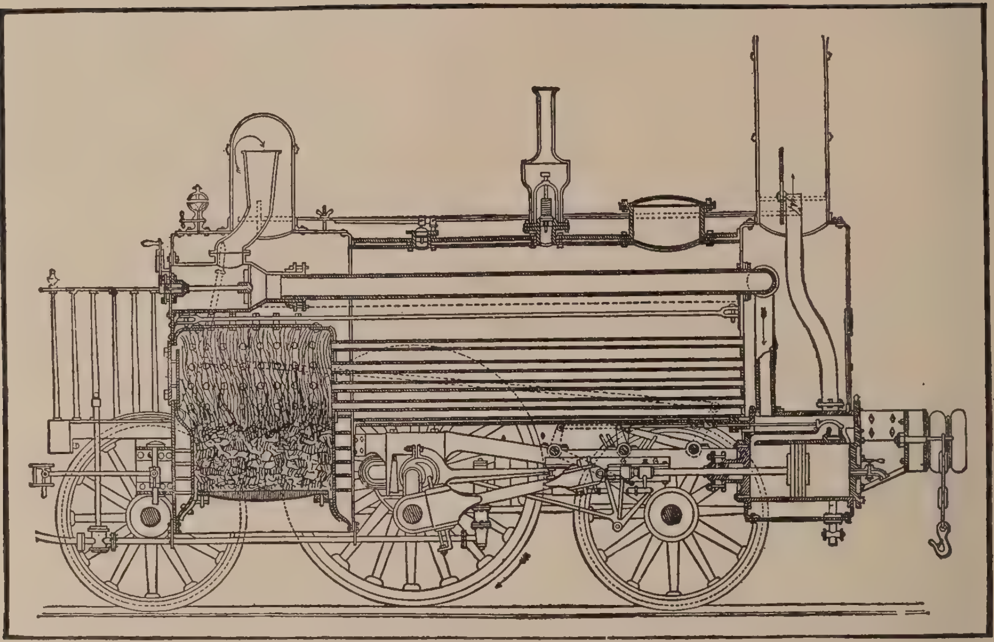


STEPHENSON'S "ROCKET"

From twenty-six to thirty miles an hour was good speed for this machine.

The winner was Stephenson's quaint little *Rocket*, which looks queer enough when placed alongside a modern mogul. Its boiler was horizontal, cylindrical, with flat ends, six feet in length and three feet in diameter. Steam was stored in the upper half of the boiler. The lower half was filled with water and had copper pipes running through it. The two-by-three fire box was just in the rear of the boiler. Above the fire box and on each side were the cylinders, of which there were two. They acted obliquely downward on the engine's two front wheels. The piston rod, as in modern American locomotives, connected with the driving wheels by a bar fastened to the outside of the wheel.

From the first the *Rocket* proved a success. On the opening day of the contests it covered twelve miles over the two miles of trial tracks in a good deal less than an hour. Stephenson offered, the following day, to satisfy the



ROBERT STEPHENSON'S STANDARD PASSENGER ENGINE, 1836

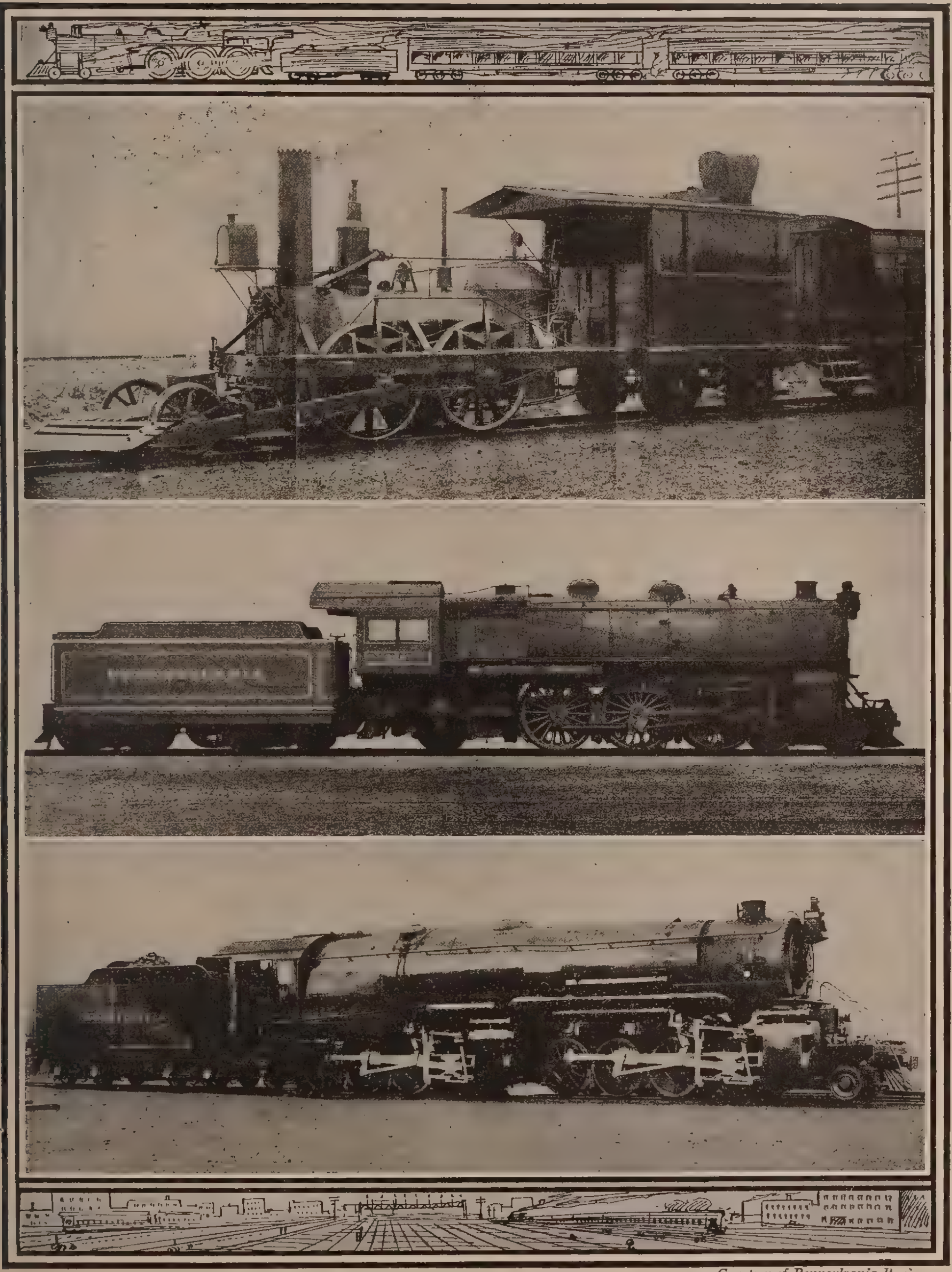
curiosity of the great crowd present by an unofficial trial of his engine. Attaching it to a car into which thirty-six passengers were loaded, he took his guests on a ride at the surprising rate of from twenty-six to thirty miles an hour.

A serious defect in this engine was the inclination of the cylinders, which produced unsteadiness. Presently Timothy Hackworth suggested horizontal cylinders, and Stephenson adopted this plan in an engine which he called the *Globe*. He followed this with the *Planet*, which became the model for engine builders the world over. It is an interesting fact that since the time of the *Planet* the general shape and arrangement of the locomotive engine has continued the same. Cold and stormy weather in our country led to the building of the cab, or house, for the engineer and fireman; and many other improvements were made, which are described elsewhere. The *Rocket* weighed a little over four tons; to-day the hundred-ton engine is a common affair. The demand for speed has brought a marked increase in the amount of steam pressure per square inch in the boilers. This has gone from 130 pounds in 1870 up to 160, and frequently 225, pounds' pressure. A much larger proportion of the energy of the steam is also utilized now, through the introduction of what is known as the "compounding principle." Compound locomotives came into use about 1890.

The increased size meant increased coal-consuming capacity, and how to keep the fire box full became a problem. The big engines of the present time tax the strongest firemen. Mechanical stokers have been successfully applied to large locomotives. The use of liquid fuel is another step towards higher efficiency.

AMERICA'S SHARE IN PERFECTING THE LOCOMOTIVE

Concerning the achievements of American inventors *Current Mechanics* makes this summary: "George Stephenson, an Englishman, built the first locomotive, but the high-pressure, high-speed engine itself, so simple and efficient, is the invention of Oliver Evans, an American; the multitubular boiler, so essential to



Courtesy of Pennsylvania R. R.

EARLY LOCOMOTIVE AND LATER FORMS OF DEVELOPMENT OF LOCOMOTIVE

A striking comparison of the first locomotive used on the Pennsylvania Railroad with two of later date on the same line.

Photo, *Ewing Galloway, N. Y.*

LOCOMOTIVE WHICH PUSHES TRAINS UP STEEP GRADES

This huge locomotive used in a mountainous region weighs 416 tons and has twenty-four drive wheels.

rapid steam making, and without which no train could be kept running at a rate of more than ten miles an hour, was invented by Nathan Read, an American; it, in turn, is carried in compact form by four-coupled driving wheels and a four-wheel truck, a combination invented by John B. Jervis, an American; while the driving wheels themselves, of cast iron, made hollow, are the invention of Thomas Rogers, a Jerseyman, who also was among the first to use weights secured in the wheels to counterbalance the reciprocating parts.

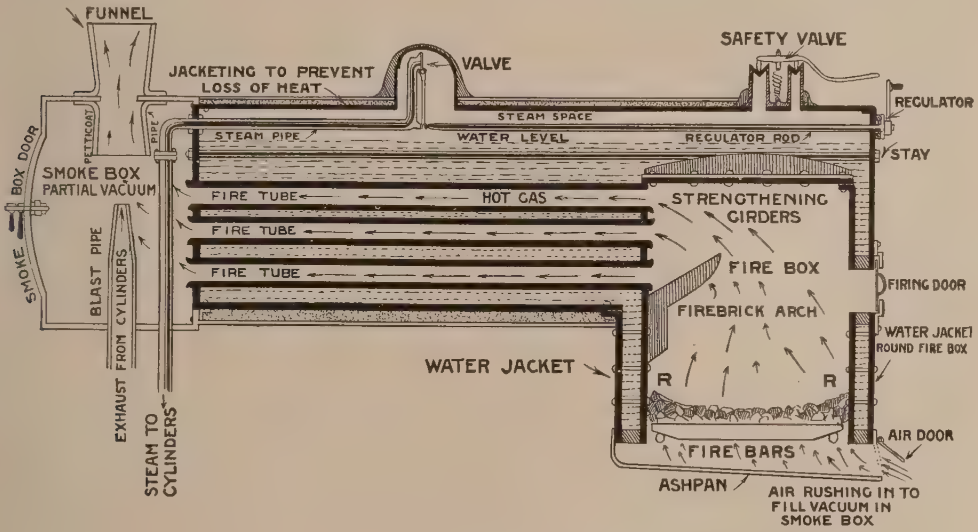
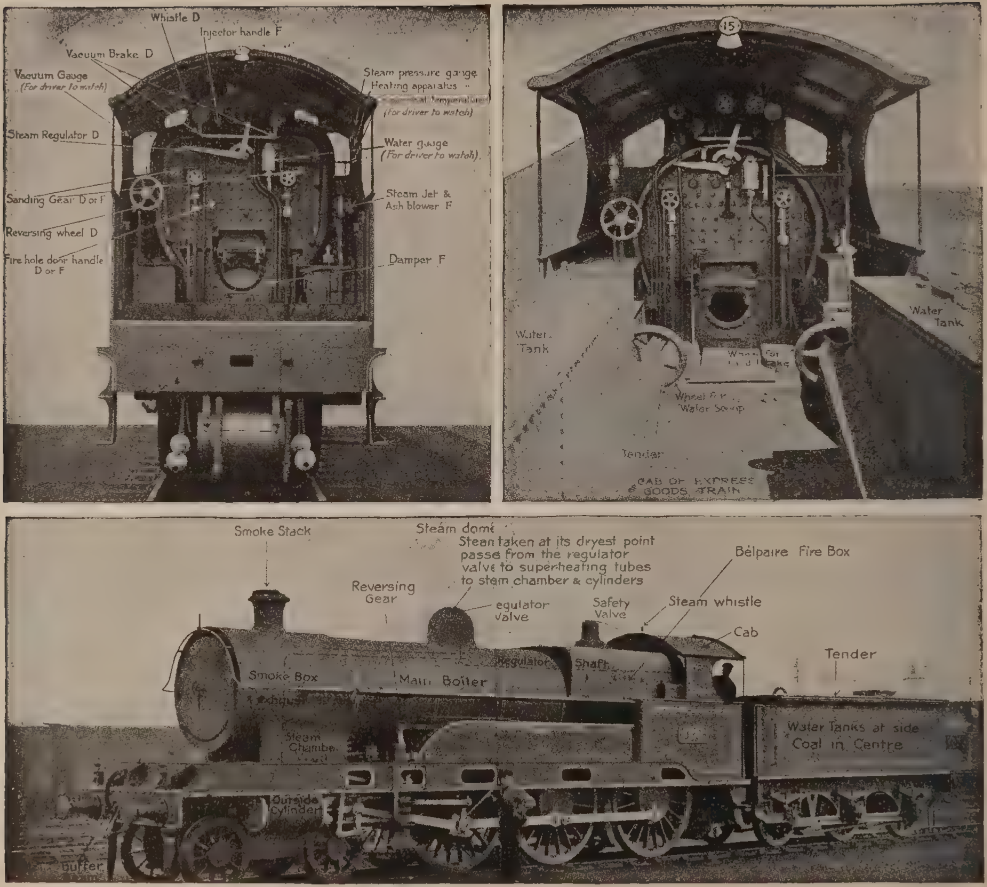

FUNNEL
JACKETING TO PREVENT LOSS OF HEAT
VALVE
SAFETY VALVE
REGULATOR
STEAM SPACE
PETTICOAT
PIPE
STEAM PIPE
WATER LEVEL
REGULATOR ROD
STAY
BOX DOOR
SMOKE BOX
PARTIAL VACUUM
SMOKE
FIRE TUBE
HOT GAS
STRENGTHENING GIRDERS
FIRE TUBE
BLAST PIPE
FIRE TUBE
FIRE BOX
FIRING DOOR
FIREBRICK ARCH
WATER JACKET ROUND FIRE BOX
EXHAUST FROM CYLINDERS
WATER JACKET
R
R
STEAM TO CYLINDERS
AIR DOOR
FIRE BARS
ASHPAN
AIR RUSHING IN TO FILL VACUUM IN SMOKE BOX

DIAGRAM SHOWING THE ACTION IN A SIMPLE LOCOMOTIVE BOILER

“Allen paper wheels — a thoroughly Yankee notion, the invention of Richard Allen, an American — carry the engine truck, while the tender is sustained by cast-iron wheels with chilled tread, invented by Ross Winans of Baltimore, and the single-bar frame holding cylinders placed horizontally and bolted together in the center are another combination designed in part by Winans and perfected by William Mason of Taunton, Mass. Moreover, all the pipes and joint connections are secured against leakage by the ground joint, which was invented by M. W. Baldwin of Philadelphia, while expansion braces, designed by Thomas Rogers, already referred to, give the fire box a secure hold on the frame, yet permit the boiler to lengthen or shorten, as change of temperature requires.

“Continuing the list, the weight of the engine is distributed evenly to the axle boxes by means of equalizing levers, invented by Joseph Harrison, a Philadelphian, while two fixed eccentrics, invented by William James of New York, give movement to an Allen slide valve, balanced by a device, invented by George Richardson, an American, who also devised the pop safety valve, the most perfect device known for relieving boiler pressure. The slide valves are operated by Baker-Pilliod motion, an American invention, and are oiled by a Detroit lubricator. Spark throwing is restrained by an extended smoke-box combination, invented by E. M. Reed, once general manager of the New Haven system, and combustion is promoted and smoke making prevented by a specially devised fire box constructed of mild steel made in Pittsburgh by the Baldwin Locomotive Works of Philadelphia, the enginemen all the while sitting comfortably in a convenient cab, first designed by David Matthews, an American, but since improved by many builders.

“And last, while the locomotive thunders along the steel highway at high speed over chasms spanned by traceries of steel and down


Whistle D
Injector handle F
Vacuum Brake D
Vacuum Gauge (For driver to watch)
Steam Regulator D
Sanding Gear D or F
Reversing wheel D
Fire hole door handle D or F
Steam pressure gauge
Heating apparatus
(For driver to watch)
Water gauge (For driver to watch).
Steam Jet & Ash blower F
Damper F
Water Tank
Water Tank
Wheel for Hand Brake
Wheel for Water Scoop
Tender
CAB OF EXPRESS & GOODS TRAIN
Smoke Stack
Steam dome
Steam taken at its dryest point passes from the regulator valve to superheating tubes to steam chamber & cylinders
Reversing Gear
egulator Valve
Safety Valve
Belpaire Fire Box
Steam whistle
Cab
Tender
Smoke Box
Exhaust
Main Boiler
Regulator
Shaft
Steam Chamber
Outside Cylinder
Buffer
Water Tanks at side Coal in Centre

THE POWERFUL LIGHTNING EXPRESS LOCOMOTIVE (BRITISH)

The pictures enable us to look inside of the engineer's cab and see the different parts of the machinery. If the reading is too fine for your eyes, it will pay you to use a magnifying glass.

steep mountain grades, the engineer sits calm and steadfast, secure in the knowledge that locomotive and train are entirely in hand, since a turn of a lever will cause every wheel to be gripped by viselike brakeshoes applied by the greatest life saver of modern times, the Westinghouse automatic air brake."

At least seventeen American inventors are therefore represented in the steam engine of to-day.

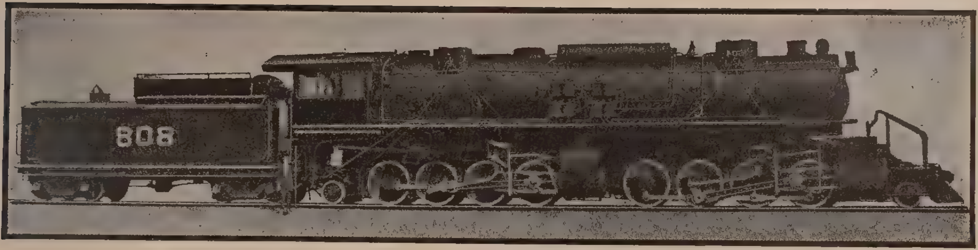
THE AIR BRAKE

"Do you mean to tell me that you can stop a railroad train by wind?"

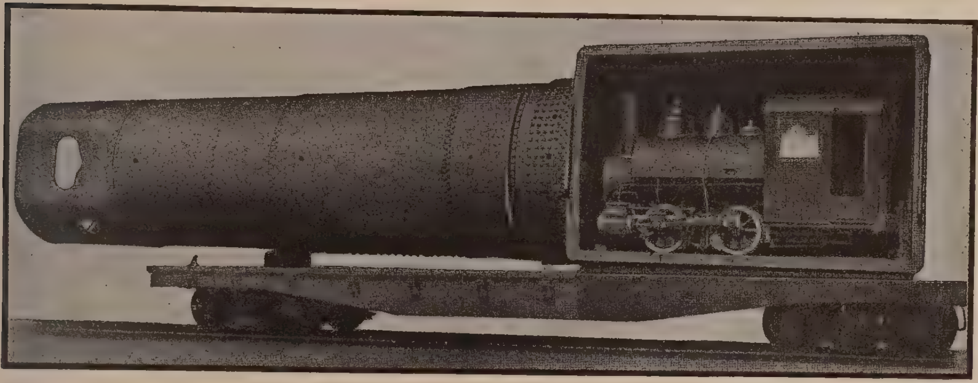
"Well, yes; inasmuch as air is wind, I suppose you are right."

"I have no time to waste on fools."

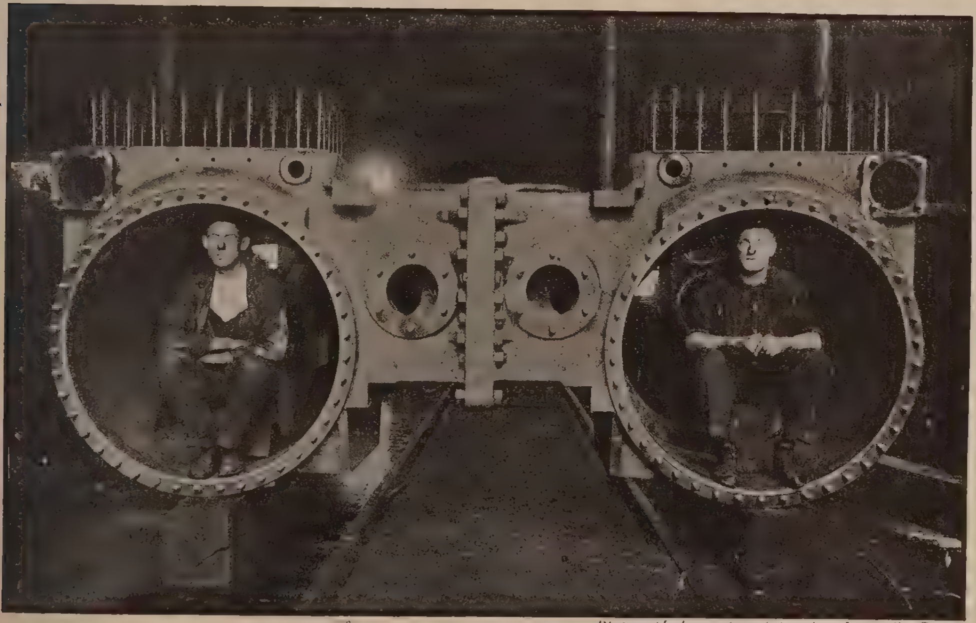
This conversation took place between Commodore Vanderbilt, the railway magnate, and George Westinghouse, the inventor of the air brake. But it is not the way of inventors to give up at the first repulse. Westinghouse continued to seek acquaintances by whose help he might push his brake. At last he met Andrew Carnegie, Robert Pitcairn, and Ralph Bagley at Pittsburgh, and was able to interest them in his safety device. All he asked was a chance to exhibit it. These men agreed to stand



ARTICULATED COMPOUND TYPE OF FREIGHT ENGINE, ONE OF THE MOST POWERFUL YET BUILT



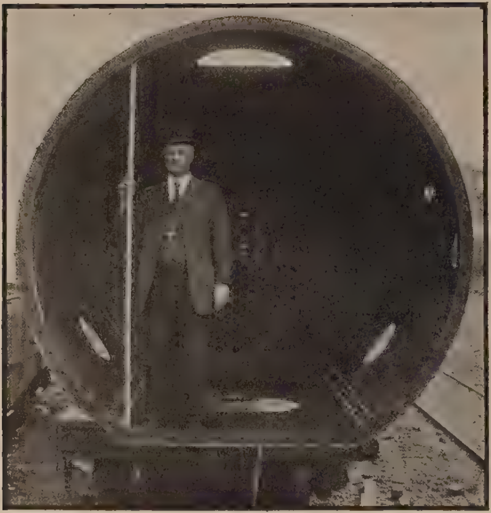
BOILER OF AN ARTICULATED COMPOUND LOCOMOTIVE



Photographs by courtesy of American Locomotive Co.

LOW-PRESSURE CYLINDERS OF ARTICULATED COMPOUND LOCOMOTIVE

This type of engine was designed to solve the problem of hauling increasingly heavy loads on the steep grades of the Virginian Railway. Here are found practically two power plants in one locomotive.



FRONT VIEW OF BOILER OF COMPOUND ARTICULATED LOCOMOTIVE

the expense of equipping a single train, and the first trial took place in October, 1868, on the Panhandle railroad between Pittsburgh and Steubenville. The experiment was so successful that the wonderful brake that could stop a train in its own length came into general use almost immediately.

Trains are of such weight and travel with such speed nowadays that the system of hand brakes which at first served to bring them to a stop long ago became inadequate and recourse had to be had to far greater power much more readily applied. All large and swift trains the world over are now equipped with the Westinghouse automatic air brake, which makes it possible to apply all the brakes at once on all the cars of a train, no matter how long. This is one of the most wonderful inventions connected with railroading. A study of the diagrams will show how it works.

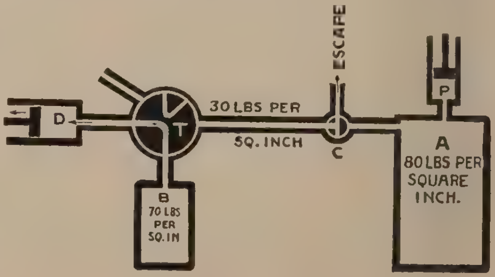
In the diagram, *P* is a steam-driven air pump on the engine, which compresses air into a reservoir, *A*, situated below the engine or tender, and maintains a pressure of from eighty to ninety pounds per square inch. A three-way cock, *C*, puts the train pipe into communication with *A* or the open air at the wish of the driver. Under each coach is a triple valve, *T*, an auxiliary reservoir, and a brake cylinder, *D*. The triple valve is the most noteworthy feature of the whole system.

Now for the way it works. When the engine is coupled to the train, the compressed air in the main reservoir is turned into the train pipe, from which it passes through the triple valve into the auxiliary reservoir under each car, which it fills until it has a pressure of eighty pounds to the square inch. Until the brakes are required the pressure in the train pipe must be kept up. If the train-pipe pressure is reduced, the triple valve at once shifts, putting *B* in connection with the brake cylinder *D*, and cutting off the connection between *D* and the air, and the brakes go on. To get them off, the pressure in the train pipe must be made equal to that in *B*, when the valve will assume its original position, allowing the air in *D* to escape.

The strength of the force with which the brake goes on depends on the reduction of pressure in the train pipe. By a slight reduction air would be admitted very slowly from *B* to *D*; a full escape from the train pipe, on the other hand, would open the valve wide. In the latest form of triple valve is included a device which, when air is rapidly discharged from the train pipe, as in the case of an emergency application of the brake, throws open a port through which compressed air is also admitted from the train pipe directly into *D*, which gives a double advantage.

THE INVENTOR OF THE AIR BRAKE

George Westinghouse was born October 6, 1846, at Central Bridge, N. Y. His father



WESTINGHOUSE AIR BRAKE

had invented one of the first threshing machines introduced into the United States. There were five boys in the family, and before they were sixteen years old, each had built an engine of original pattern with his own hands. George made a rotary engine when he was fifteen. He enlisted in the Civil War and served in the 12th New York Volunteers, reenlisted in the cavalry, and later served as an engineer on gunboats. At the close of the war, after a short term at Union College, he entered his father's factory at Schenectady, N. Y., and devoted himself to invention. The air brake was suggested to him by a railroad collision which he witnessed, and for which the poor brakes were responsible.

The mind of Westinghouse was always at work. No sooner was the air brake in use than he was developing other inventions, among them a device for transporting natural gas, which he perfected in spite of the jeers of leading engineers who had failed. Westinghouse was forced to fight opposition continually, but that is the lot of inventors. It was fifteen years before he was able to overcome the obstacles to the use of the alternating electric current which were deliberately thrown in his way. Yet the introduction of this system, experiments with which had been made in Europe, eventually won him almost as much fame as the invention of the air brake. Power can be transmitted a much longer distance by the alternating than by the direct current, and doubtless it is due to the stubborn persistence of Westinghouse that many of the smaller cities and towns have electric lights to-day.

As the World's Fair at Chicago approached, Westinghouse entered a bid for the electric-lighting contract which was one million dollars lower than that of the nearest bidder. He was given the contract, but in the face of violent criticism inspired by his enemies. The success achieved at the fair was so great as fully to demonstrate the value of the alternating system, and the managers were vindicated. Certainly the stockholders were satisfied, for they divided just one million dollars, the amount saved by accepting the bid of Westinghouse.

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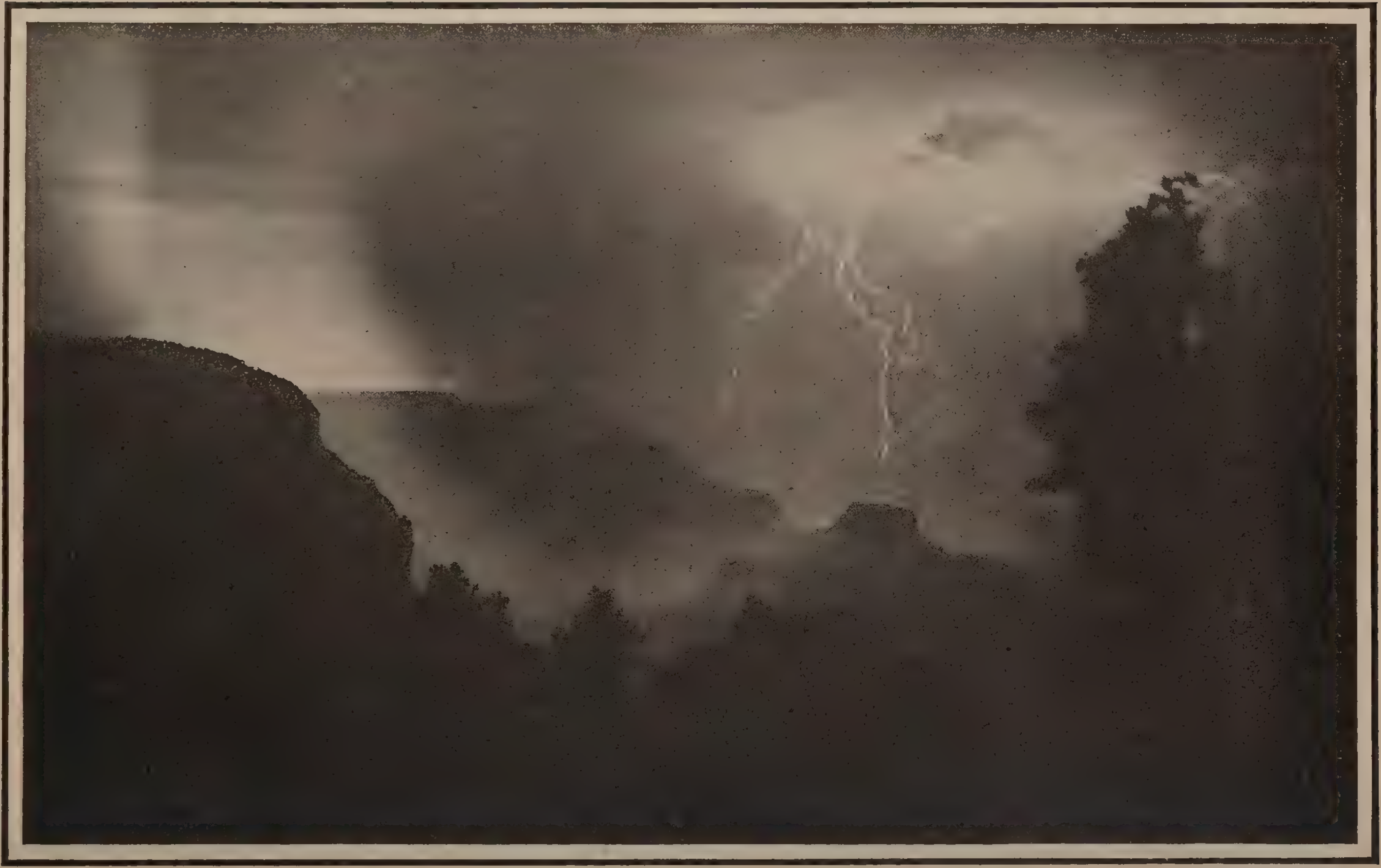
GEORGE WESTINGHOUSE

The famous inventor of many devices for safety in traveling and for the general progress of the world.

Following his success at Chicago, the inventor designed the ten giant alternators at Niagara, which have become monuments to his genius. In 1912 he was awarded the Edison gold medal for his achievements in the development of the alternating-current system. He received it at a banquet which was attended by many engineers who had hotly opposed his efforts to introduce this system.

It is worth noting that some of the most important of Westinghouse's inventions had as their object the conservation of human life. He fathered the modern automatic railroad signal and devised the automatic couplers used in the New York subways, where a million passengers a day are carried. When one man does so much, some of his achievements are likely to be overlooked; but it is worth while pointing out that he was the originator of the Saturday half-holiday in this country. He was the friend of labor and understood the laboring man. He passed away March 12, 1914, universally recognized as one of the world's foremost inventors, and a captain of industry to whom this country owes much of its rapid development.



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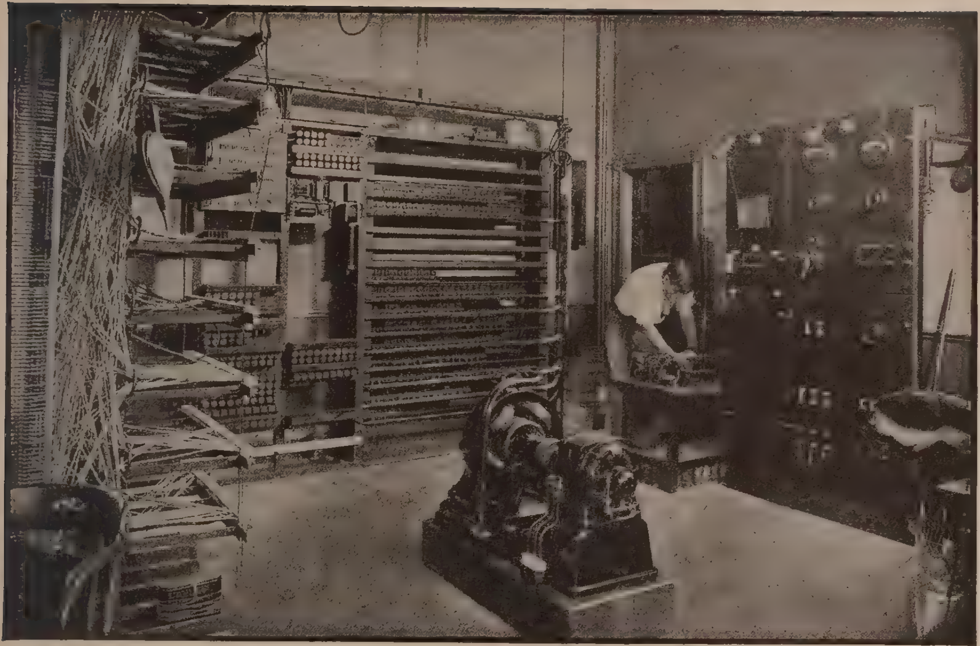
AN ELECTRICAL DISPLAY DURING A THUNDERSTORM



Courtesy of N. E. Tel. & Tel. Co.

POWER AND TERMINAL ROOM IN A TELEPHONE EXCHANGE

ELECTRICITY

OUR MYSTERIOUS SERVANT AND WONDER WORKER

IF you rub a bit of amber, or resin, or a bit of glass on a dry coat sleeve you will find that it will attract bits of paper and hold them there. This is a manifestation of electricity. The ancient Greeks knew that amber would act in this way and they poetically said that the amber had a soul because it could attract. We do not know to-day what this force really is, though we call it electricity. As of old, in the Arabian tale, Aladdin rubbed the lamp and called forth a genie with mighty powers, so to-day man calls forth this same mysterious power which the rubbed amber showed the Greeks, and makes it light and heat and transport him round the world.

The Greeks said that the thunderbolt was a javelin hurled by Zeus, and not until Benjamin Franklin called this mysterious power down the kite string from the thundercloud into his Leyden jar did men know surely that Jove's thunderbolt and the soul of the amber were one. Yet both are manifestations of that still, mysterious force which we call electricity. We know its power; we harness and control its energies and make it our very slave, but we do not yet know what it is. Our whirling dynamos call it up as Aladdin did the genie. We send it through a thousand miles of wire and make it do our bidding at the other end, but we do not know whence it comes or whither it goes. We call it a mode of motion or a manifestation of energy, but its very source is as unknown as that of life itself.

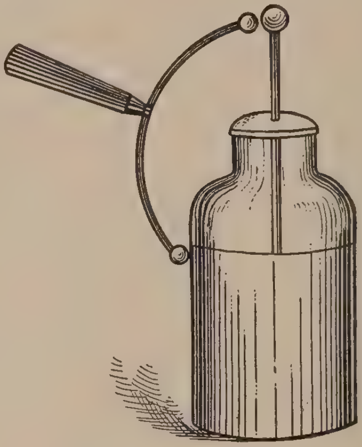
Its action in passing along a wire may be likened to the flow of water through a pipe. Even as a pipe must be clean and free from anything that will interfere with the flow of water, so a conductor of electricity must offer the least resistance possible to the passing of the current. One of the best materials for conductors is copper wire, and as copper may be obtained in sufficient quantities to make the cost reasonable, it is what is generally used.

The walls of a water pipe form a barrier through which water cannot pass, and it flows along the inside of the pipe as it may be directed. Any holes or cracks in the pipe walls will allow the water to leak through, and, with a large enough leak, the flow of water in the pipe will cease. The copper wire through which electricity flows corresponds to the space inside of a water pipe. To prevent leakage and to cause the current to flow through the designed conductor the wire must be covered with some nonconducting or insulating material. This is usually made of fiber, rubber, or some other substance through which electricity will not pass. If this insulation becomes destroyed at any point, the leakage of the electricity at that point will short-circuit the current and it will cease to flow through the wire and will escape through the nearest conductor.

If an obstruction of any kind is placed in a water pipe, for instance, a substance through which water will pass only with difficulty, the energy of the water used up in trying to get through this substance will cause it to become heated. In the same way if electricity is forced through a poor conductor, one offering considerable resistance to the flow of the current, this material will be heated by the current. This is the principle of electric stoves and heaters.

BOTTLED POWER — THE LEYDEN JAR

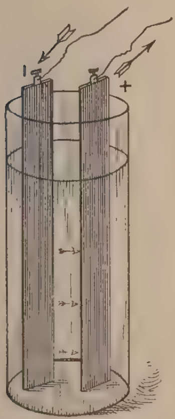
Two hundred years ago small machines were made in which, by turning a crank and making a glass globe or disk revolve, feeble electricity was generated. In 1745 Dean von Kleist, in Germany, discovered that this force might be bottled, that a nail or a piece of brass wire in a dry glass vial once electrified held the force for some time and might be made to give it forth in a somewhat startling way. Under the right conditions sparks would spring from it and people touching the nail received a severe shock. Out of this apparatus grew the Leyden jar, a glass bottle coated outside and in with tin foil, the two being separated by the glass. The inner coating is connected with a metallic knob protruding from the cork. To charge the jar the outer coating is connected with the earth and electricity is excited in the inner coating with an electrical machine. The machine excites a positive electricity on one side of the glass, a negative on the other, and the glass keeps the two apart. But if a path be provided for the two electricities to flow to one another, they will do so. To hold the jar in one hand and put the other near the knob is to make oneself the path through which the currents come together and to receive a shock which is a strong one if the jar is highly charged. In 1752 Franklin charged a Leyden jar from a thundercloud, by drawing the electric current down a kite string, and this proved that the lightning was but a manifestation of electricity. This kind of electricity is called "static."



A LEYDEN JAR

ELECTRIC CELLS AND BATTERIES

We speak of electricity as a fluid because it seems to flow from one substance to another. If we put two metals in an acid solution which acts differently on the two, then, if there is a connection by wire, a "current" will flow from one to the other and then through the external wire circuit. If the wire is broken, the current stops. Thus we have the voltaic cell, invented by an Italian named Volta. Various metals and other substances are used, as well as various solvents, but the principle is the same in each case. Many voltaic cells connected by wires are called a "battery," usually a "galvanic" battery, from another distinguished Italian, whose studies in electricity led up to the invention of the battery.



A VOLTAIC CELL

The discharge of a Leyden jar is a miniature lightning flash, that of a galvanic battery is a current which may flow for a long time. It produces electricity in great quantity but of little pressure, and is in use in many ways where such an electric current is desired. The dry cell is now preferred because it contains no liquids and can be used in any position. A container of zinc is filled with an absorbent mixture soaked with chemicals, in which a rod of carbon has been embedded. A current will flow through a wire connecting the zinc case and the carbon rod. Another familiar source of electricity is the storage battery. This does not make electricity, but has the power of storing up current from a generator and giving it out again when a circuit is made.

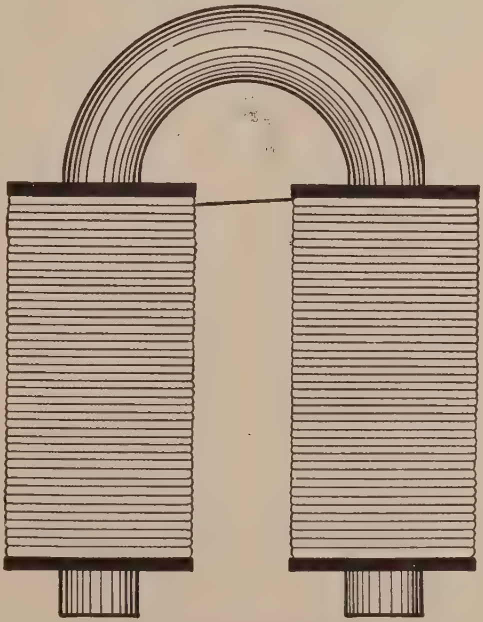
MAKING MAGNETS

The ancients knew of a kind of rock that would attract iron, and called it the "loadstone." It is an ore of iron and is a natural magnet. By rubbing steel with this rock the steel becomes magnetized, and thus primitive magnets were made. Magnets are now made by means of the electric current. The earth itself is said to be one great magnet. If a coil of wire through which an electric current is passing surrounds a bar of soft iron, it makes it a magnet while the current flows. Shut off the current and you have a bar of iron, not a magnet. By making and breaking the circuit the bar will alternately attract and release another bar of iron near it. In this lies the principle of the electric telegraph and many other devices which use a current from a battery or a dynamo. A simple apparatus devised on this principle is known as the "electromagnet."

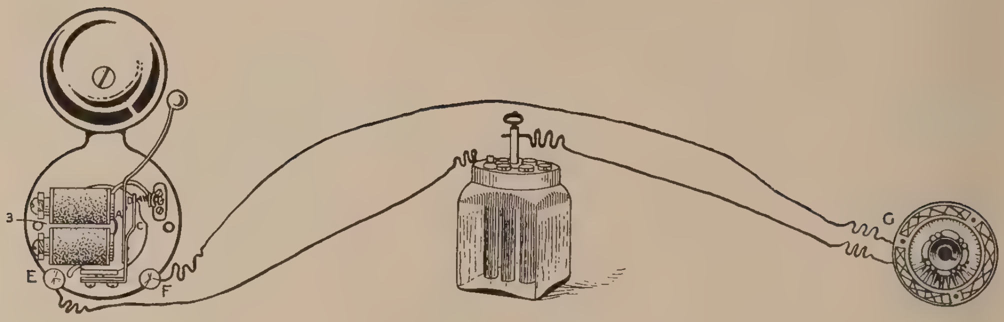
ELECTRICAL MAGNETS

When an insulated wire is wound round and round a steel or iron bar from end to end, and its ends are connected with the terminals of an electric battery, a current flows round the bar and the bar is magnetized. Increase the strength of the current and multiply the number of turns of wire, and the attractive force of the magnet is correspondingly increased. Then disconnect the battery. If the bar is of iron, the magnet will lose its attractive force; but if of steel, it retains it in part. The first electromagnets were made in the shape of horseshoes or straight bars. Now two shorter bars riveted into a plate are generally used. Coils of wire wound round each bar are so connected as to form a continuous whole, but the wire of one coil is wound in the direction opposite to that of the other. The free end of each goes to a terminal of the battery.

We have now considered electricity in two of its forms—static in the Leyden jar and current in the galvanic battery—and are ready to pass to some of its applications.



AN ELECTROMAGNET



AN ELECTRIC BELL AND CURRENT

One of the simplest but one of the most important uses of electricity.

THE FIRST USES MADE OF ELECTRICITY

THE ELECTRIC BELL

ONE of the most common devices with which to begin is the electric bell, which is now in common use in every home. The buzzer, often found where the noise of a bell would be objectionable, operates in the same manner as the bell. In the buzzer, the bell and the striking hammer are removed, leaving only the electromagnet unit. Thus a sharp buzzing sound is produced instead of a ringing. The push button shown in the bell circuit is a small electric switch made of springy metal. When the button is pushed, this switch is closed and allows the current to flow. When pressure on the button is released, the switch opens, the flow of current ceases, and the bell stops ringing.

Above we have a sketch of an electric bell and circuit. When no current is flowing through the system, the small platinum point at *D* on the flat spring *C* fastened to the soft iron hammer *A* rests against another platinum point on the pillar at the right which is connected with the electromagnet.

If the circuit is closed by the push button *G*, the current will flow from the battery to the terminal *E*, then through the electromagnet *B* around through the touching platinum points and the bell hammer to the terminal *F*, thence back to the battery through *G*.

As soon as the current passes through the coils of the electromagnet the magnetic force thus created causes the soft iron bell hammer to spring quickly against the ends of the magnet, the hammer striking the bell. This action causes the platinum points at *D* to separate. Instantly the current ceases flowing, the magnetic force disappears, and the spring at the lower end of the hammer causes this piece to move quickly to the right, thus bringing the platinum points again into contact. The current immediately starts again and the above process is repeated. Thus it is seen that the bell hammer is caused to vibrate rapidly, striking the bell at each vibration as long as the button *G* is depressed.

The electric bell plays an important part in telephonic installations, to call the attention of subscribers, and in automatic fire and burglar alarms, in railway signaling, and in a host of other ways in calling attention from a distance.

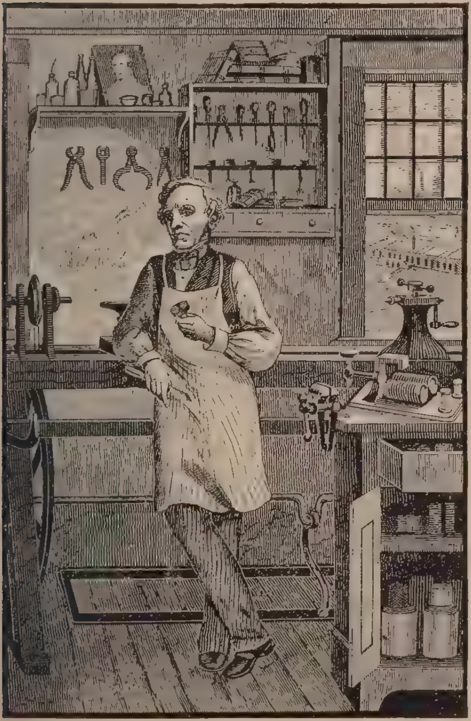
SAMUEL F. B. MORSE, INVENTOR OF THE TELEGRAPH

One of the most wonderful inventions ever worked out by man is the telegraph. Samuel F. B. Morse, whose genius gave this instrument to the world, was, strangely enough, a portrait painter, who went to England to study with the famous Washington Allston.

But, in spite of his talent for painting, it turned out that Samuel Morse did not become an artist after all. It happened that one day when crossing the ocean he overheard at table a discussion about electromagnetism and was greatly interested when told that electricity passed without difficulty through wires of any length.

"If that is so," said Professor Morse, "why should not intelligence be transmitted by electricity?"

Morse was then forty years old and had already secured several patents on other inventions. He set to work, denying himself every comfort, and put all his time and money into the perfection of this new idea. In a tiny room in a down-town New York office building he ate, slept, and worked, cooking his own simple meals and laboring far into the nights. At last the instrument embodying his idea was made. Then, on March 3, 1843, the future of the device was to be decided. Before Congress was a bill to put into operation a forty-mile telegraph between Washington and Baltimore. The House had passed the bill. On the decision of the Senate hung Morse's fate. Anxiously the inventor presented himself at the Capitol to await the news which meant so much to him. He stayed until nearly midnight and then went back to his hotel discouraged because the Senate had so much business that it seemed impossible for any decision about the telegraph to be reached that night. But the next morning he was astonished to be congratulated by Miss Annie G. Ellsworth, the daughter of the Commissioner of Patents, and to learn that the bill to install the telegraph had really passed.



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MORSE IN HIS WORKSHOP

S. F. B. MORSE

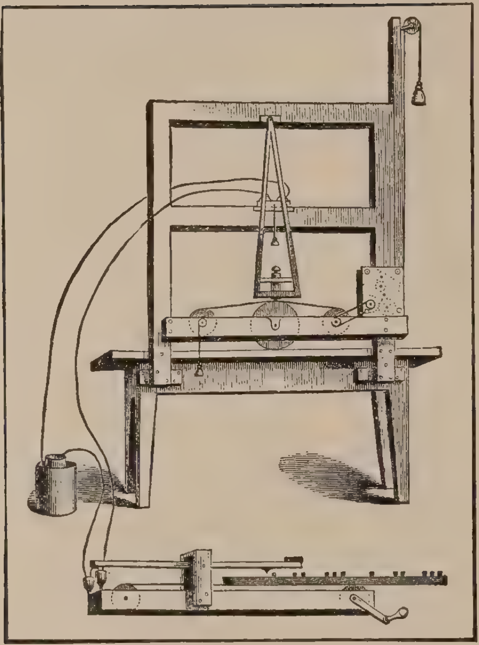
This famous inventor was awarded numerous honors by foreign governments, among them orders, crosses, and large sums of money. Probably no other American has received so many marks of distinction.

"You shall send the first message," said Professor Morse to Miss Ellsworth.

Later, when the line was ready, he asked her to dictate it.

"What hath God wrought?" were the words of the first telegram flashed over the wire.

Mr. Alfred Vail, a friend of Professor Morse, received the message at Baltimore and repeated



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THE FIRST TELEGRAPHIC INSTRUMENT AS EXHIBITED IN 1837 BY MORSE

it, and afterwards a few other messages were sent and promptly answered. The telegraph was a success!

On May 26, 1844, two days after the sending of this first message, the National Democratic Convention met in Baltimore and nominated James K. Polk for President and Silas Wright for Vice President. Mr. Wright chanced to be in the Senate when the news was telegraphed by Mr. Vail from Baltimore to Professor Morse, who was in the Capitol building at Washington. When the message was taken to Mr. Wright he at once said: "Tell them I cannot serve." Back over the wire went the dispatch. When it was received at the convention it was credited merely as an attempt of Mr. Wright's enemies to take the election from him. A committee was sent to Washington to find out the facts. The next day they returned. The message delivered over the wire was correct! After this proof no one doubted the usefulness of the telegraph.

In the meantime an Englishman and a German were also trying to perfect a telegraph, and when Mr. Morse went to Europe to try to get his instrument installed there he met them. Each of the three applicants presented his invention before the foreign board, and then the German inventor, who had been examining Professor Morse's machine, cried, "Gentlemen, I willingly withdraw from the field. Mr. Morse's invention is better than mine."

About fifteen years later, in 1858, the first Atlantic cable was laid. Following this idea the telegraph and cable service was extended until it was possible for Queen Victoria, on the sixtieth anniversary of her accession to the British throne, to touch an electric button in her palace and send to forty distant parts of her realm the message:

"From my heart I thank my beloved people. May God bless them."

Within sixteen minutes a reply came from Ottawa, Canada, and before the queen had reached London Bridge responses had come from the Cape of Good Hope, Africa, and from Australia.

EXPLANATION OF THE TELEGRAPH

The electric telegraph in its simplest form consists of a single zinc-coated, iron or hard-drawn-copper wire connecting the two places between which messages are to be sent, with two instruments, and a battery for producing the electric current at each end. One of the instruments at each end is the transmitter for sending, and the other the sounder for receiving electric impulses, by which, by means of arbitrary signs, communication is carried on. The long line of wire is connected at one end with the transmitter or key. This is connected through the battery with the sounder, from which a wire runs to the earth.

On the other end the long wire connects with the sounder, then through the battery to the key, and from there to the earth. The earth acts not as a conductor of electricity in the sense that the wire does, but as a place where it may be stored, so that when a current passes through the long connecting wire the amount of electricity taken from the earth at one end will be restored to it at the other.

The action of the telegraph is somewhat similar to that of the electric bell. The key or transmitter which is shown in the illustration corresponds to the push button, and is simply a switch, the two points of which are held apart by a spring, and by which the circuit may be closed by pressing down on the button at the left. When the key is not in use the circuit is closed by pushing the small lever in the notch as shown, so that messages may be sent from the other end.

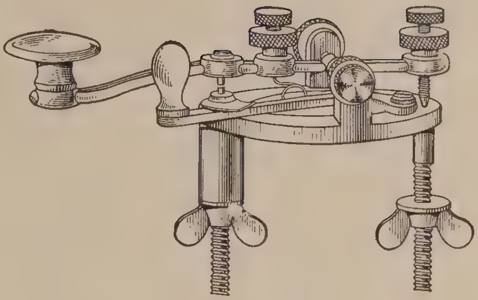
The sounder, which produces the audible signals, corresponds to the electric bell. It has an electromagnet opposite the ends of which a piece of soft iron is arranged connected to a lever, so that when the circuit is closed by the key at the other end, the soft iron immediately jumps into contact with the electromagnet and causes the lever to click against a curved bar, which it may hit both going up and coming down. It is by the variation in length and intensity of these clicks that the message is spelled out by the operator. The telegraph sounder differs from the electric bell in that there is only one up-and-down click for one depression of the key.

The characters used by Morse to designate the letters of the alphabet, numerals, etc., were made up of long and short dashes, dots, and spaces arranged in various combinations. The first machine invented by Morse was arranged to trace on paper these combinations. The clicks were not used until a later period. Hence the reason for using dots and dashes for characters.

The simple instruments invented by Morse have since undergone many improvements, although there has been no radical departure from his idea.

THE RELAY

Sending by direct current over a wire charged with a battery at the sending end can only be done for a limited distance. For a long time long-distance messages had to be repeated at intermediate stations. By the invention of the relay this difficulty has been overcome. A relay is an instrument that responds to the message which it receives and sets in motion a new battery, known as the "local battery."



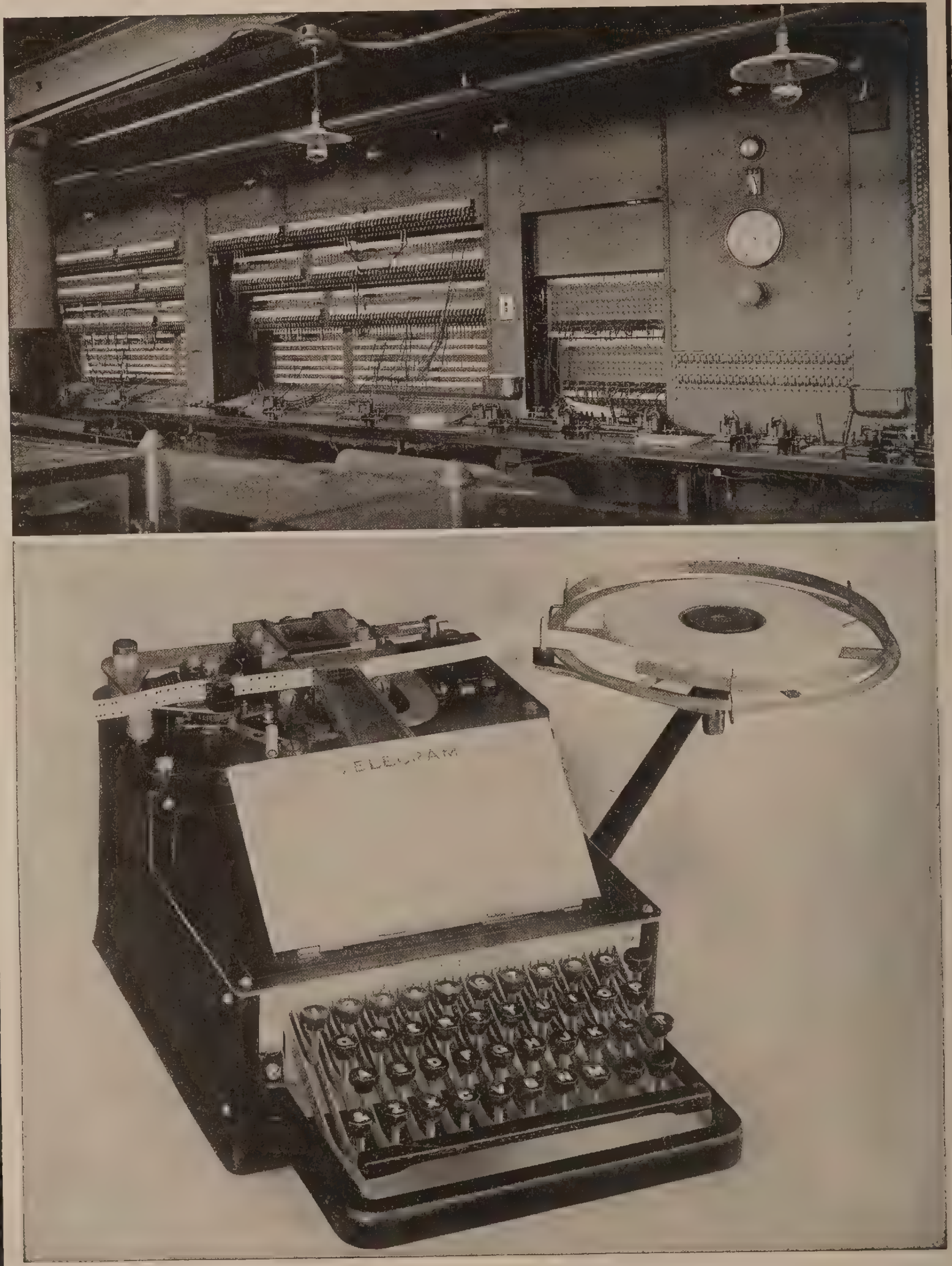
A TELEGRAPH KEY

MULTIPLEX TELEGRAPHY

The next great advance was the discovery that two messages could be sent, in opposite directions, over the same wire at the same time. This was called "duplex telegraphy." It was soon followed by quadruplex and multiplex telegraphy. This is done by connecting one of the instruments attached to a wire, so that it is only sensitive to the impulses which *come out of the wire*, while another set sends signals *into the wire*.

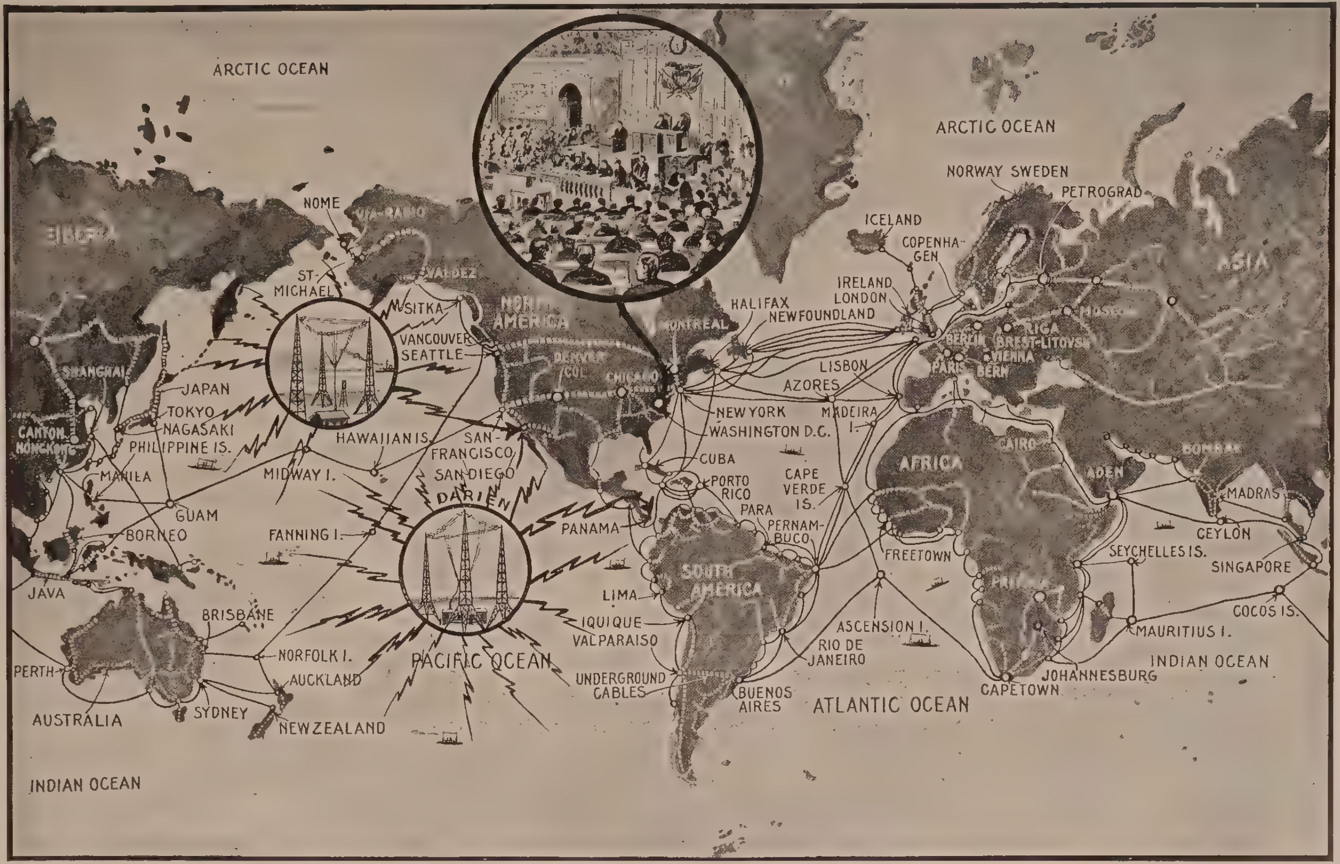
THE ELECTRIC CABLE

In August, 1858, the stupendous feat of laying an electric cable twenty-five hundred miles across the Atlantic Ocean was accomplished after several failures, and messages were sent by its means, showing how vastly invention and enterprise had extended the power and scope of the electric telegraph. A hundred minor inventions and devices had gone to this increase of power, the greatest of these perhaps being the insulated cable, for on no part of the twenty-five hundred miles must the inclosed wires allow the electricity to escape into the sea. In that case the message would fail. In addition to this, the cable must stand the wear and tear of rough rocks and the sway of currents. Thus the first cable laid between Calais and Dover across the English Channel soon gave out. But in 1851 another was laid, which is said to be in use to this day. The conductor of this cable was not a single wire of copper, but four wires, wound spirally to combine strength with flexibility, covered with



TOP: LOOP BOARD ON CIRCUIT SWITCHING SYSTEM OF A LARGE TELEGRAPH OFFICE. BOTTOM: TAPE PERFORATOR USED IN TELEGRAPHY

HOW A PRESIDENT'S MESSAGE IS CARRIED AROUND THE WORLD


ARCTIC OCEAN
NOME
ST. MICHAEL
SITKA
VALDEZ
VANCOUVER
SEATTLE
NORTH AMERICA
DENVER COL
CHICAGO
MONTREAL
HALIFAX
NEWFOUNDLAND
IRELAND
LONDON
ICELAND
COPENHAGEN
NORWAY SWEDEN
PETROGRAD
ARCTIC OCEAN
ASIA
BERLIN
RIGA
BREST-LITOVSK
VIENNA
PARIS
BERN
LISBON
AZORES
MADEIRA I.
NEW YORK
WASHINGTON D.C.
CUBA
PORTO RICO
PARA
PERNAMBUCO
CAPE VERDE IS.
FREETOWN
AFRICA
CAIRO
ADEN
BOMBAY
MADRAS
CEYLON
SINGAPORE
SEYCHELLES IS.
COCOS IS.
MAURITIUS I.
INDIAN OCEAN
JOHANNESBURG
CAPETOWN
ASCENSION I.
RIO DE JANEIRO
ATLANTIC OCEAN
BUENOS AIRES
UNDERGROUND CABLES
IQUIQUE
VALPARAISO
LIMA
SOUTH AMERICA
PANAMA
DARIEN
SAN FRANCISCO
SAN DIEGO
HAWAIIAN IS.
MIDWAY I.
FANNING I.
PACIFIC OCEAN
NORFOLK I.
AUCKLAND
NEW ZEALAND
SYDNEY
BRISBANE
AUSTRALIA
PERTH
JAVA
BORNEO
GUAM
MANILA
PHILIPPINE IS.
NAGASAKI
TOKYO
JAPAN
SHANGHAI
CANTON
HONGKONG
SIBERIA
INDIAN OCEAN

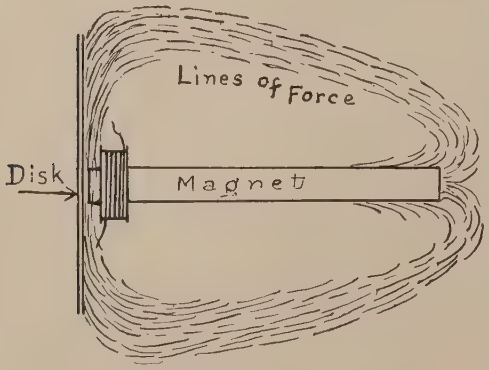
Courtesy Electrical Experimenter, N. Y.

MAP OF THE WORLD, SHOWING THE PRINCIPAL CABLES (full lines) AND LAND ROUTES (dotted lines) AND THE GREAT RADIO STATIONS AT DARIEN AND SAN DIEGO

The President speaks, and his audience becomes by modern invention the inhabitants of the four quarters of the globe.

gutta-percha and inclosed in tarred hemp. To impart additional strength, ten iron wires were wound around the hemp. This idea has been carried out in every subsequent cable.

In the Atlantic cable laid from Nova Scotia to Ireland in 1894, the central copper core is covered with gutta-percha, then with jute upon which steel wires are spirally wound, followed by a strong outer covering. For the greatest depths at sea, a cable with a diameter of seven eighths of an inch is employed. It is used for 1420 miles. As the water lessens in depth the sheathing increases in size until the diameter of the cable becomes one and one sixteenth inches for 152 miles. The cable undergoes two other enlargements until, as it touches the shore, for a distance of one and three quarter miles it has a diameter of two and one half inches. The weights of materials used are: copper wire, 495 tons; gutta-percha, 315 tons; jute yarn, 575 tons; steel wire, 3000 tons; compound and tar, 1075 tons; total, 5460 tons. The telegraph ship *Faraday*, specially designed for cable laying, accomplished the work without accident.



LINES OF FORCE SURROUNDING A MAGNET

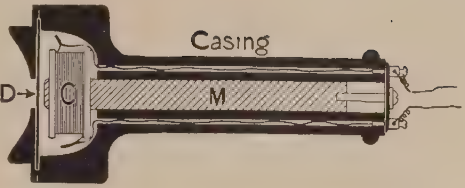
Showing the change made in their shape by bringing a metal disk against them. This is the principle on which the telephone is based.

THE TELEPHONE

IN this age of great inventions it is difficult to say that any particular invention is the greatest. Yet the telephone, in point of its far-reaching usefulness, ranks very close to first place. For the purposes of everyday life the telephone is even more useful than the telegraph. Telephones now connect one room of a building with another, house with house, town with town, and even one country with another. An infinitely greater number of telephone messages are sent than are transmitted by telegraph. Something of the great importance of the telephone in American life is suggested by the fact that while there are in the United States some 27,000 telegraph offices and 52,000 post offices, we now have over 17,000,000 individual telephones, from any one of which it is possible to talk with practically every town or city in the country. While the telegraph companies now handle about two hundred million messages each year, over twenty billion conversations are carried on over the telephone. Long-distance telephone lines now make it possible for the New Yorker to talk with Chicago, San Francisco, Washington, or other points at low cost. Regular service is even available between New York and London, linking America and Europe. Radio and the telephone have something in common, as it is a device employing the familiar vacuum tube that amplifies the voice and makes possible its clear transmission over thousands of miles of wire.

THE FIRST TELEPHONE

The first telephone that came into general use was that invented by Alexander Graham Bell, who at the time was not so much interested in telephones as he was in discovering a way of conveying speech to deaf persons by means of sound vibrations. It occurred to him that the vibrations set up by the voice might be made to act upon electric currents and thus affect some form of electric mechanism. He hit upon the telephone and made all posterity his debtor. He knew that the air surrounding the poles of an electromagnet was crowded with invisible "lines of force" and that these lines of force might have their shape altered if the surface of a metal disk were brought against them. If the disk were to vibrate with the sound of the voice, these lines of force would be made to undergo similar vibrations, and if the magnet were in connection by means of wire with a similar magnet at the other end, the lines of force at that magnet would be thrown into vibration, and a metal disk arranged as in the first case would vibrate correspondingly and the voice sound waves would be reproduced. All this is shown in simple diagram in the illustration given here, which represents the simplest form of telephone instrument. The casing, made of wood or ebonite, has a bar magnet, *M*, running through its center lengthwise, till the end protruding into the cup at the left end of the casing almost comes into contact with the metal disk, *D*. Around this protruding end is wound a coil, *C*, of fine insulated wire, which "picks up" any disturbances in the lines of force and sends them, like little electric pulse beats, along the wires to another instrument just like this one, only located at the other end of the line. This one instrument is both a receiver and a transmitter. On a line set up with such instruments no battery is needed, as the magnets themselves supply the necessary "current" sufficient to permit conversations for several miles, though one must listen very carefully as the vibrations are exceedingly small, often not exceeding one ten millionth of an inch. An ingenious "electrical boy" can without much difficulty string to a neighbor's house such a line as that of which a diagram is given at the foot of the page, and he will have accomplished what was the marvel of a generation ago, the carrying of speech by electricity, the bringing of a "voice from afar," which is the first meaning of the word "telephone."



CROSS-SECTION VIEW OF TELEPHONE RECEIVER

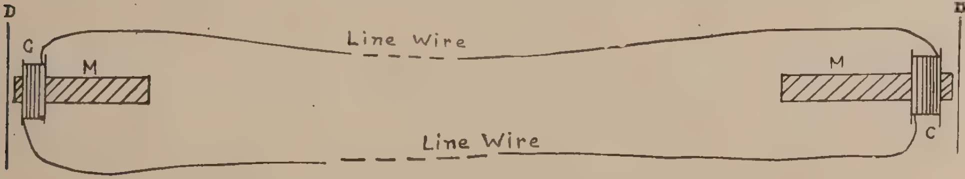
IMPROVEMENTS IN THIS SIMPLE TELEPHONE

The principle of the telephone in your house is the same as that of this simple one which you might make, but before Bell's first instrument could become of great public use several additions and improvements were necessary. Let us get to an understanding of the mechanism of the modern telephone by studying out these improvements before we run through the story of what happens when you lift your receiver.

First, in the original telephone the sounds were carried, but they were not distinct and clear as they are now. To remedy this a special "transmitter" has been invented. Then there must be some signaling or calling device. Lastly, as a network of telephones spreads over a city, there must be a central exchange where one person's line can be connected with that of another.

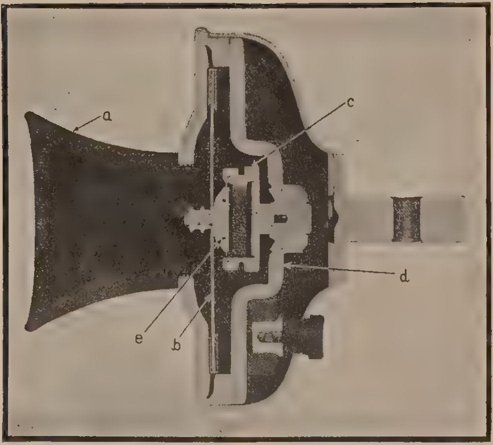
THE BLAKE TRANSMITTER

The first of these improvements was the Blake transmitter, so named after its inventor. Blake saw that the little electric "pulse beats" were actually minute variations in the resistance, resistance being the opposition or difficulty which a current meets in making its circuit. If at some point of a circuit the wires should be broken, the current would meet with great resistance, as it would have to jump across the gap; but if the break were so delicately adjusted that every sound vibration would simply modify the extent of the break, then it would be possible for the voice to set up variations in the electric current much as in the simple telephone. The



A SIMPLE TELEPHONE LINE

No electric battery is needed here. The current is supplied by the magnets.



CROSS-SECTION VIEW OF TRANSMITTER

cross-section view above shows how a standard transmitter makes this possible.

The instrument, as shown in section, consists of the receiver of air waves, the transmitter of electrical waves, and the containing case holding the parts together and protecting them.

The sound-receiving part is somewhat similar to the human ear. It consists of the mouthpiece, *a*, and the diaphragm, *b*, which is a flat disk of thin metal free to vibrate in the middle, corresponding to the drum of the ear. Shown in cross section, it appears as a thin vertical line. The air waves from the speaker's mouth pass in through the mouthpiece and beat upon the surface of the diaphragm, setting it in vibration.

The transmitter of electrical waves is a small round box, *c*, like a pill box, partly filled with fine grains of hard carbon. This is known as the "button," and is the point in the circuit at which variations in resistance are created. The back of the button, or the pill box proper, is firmly attached to the frame, *d*, of the instrument, which is heavy and cannot vibrate. The front, *e*, of the button, or the pill-box cover, is attached to the middle of the diaphragm and vibrates with it. This alternately presses the carbon granules together very slightly and then relieves the pressure.

In this instrument the current is supplied by a battery, the two wires of which are connected respectively to the front and back of the button, and the current must flow through the carbon granules. As the carbon is poured in loosely and the grains touch each other but lightly, the electrical path is somewhat broken and not a very easy one to travel. Therefore the current which flows is less than the battery would be capable of supporting were there a good solid connection. If the disk is pushed inward, however, the grains of carbon will be pressed together and the current will flow more freely. This is just what happens when one speaks into the receiver; that is, the button cover vibrates and the strength of the current varies accordingly. Thus electrical waves are sent out over the wires.

The vibration of the disk is very much less than a thousandth of an inch at most, and the rapidity of its vibration varies from 200 to 3000 movements per second. Is it not marvelous that this little box of carbon granules should be able to translate sound waves into electrical waves so faithfully that when translated back into sound waves again in a telephone receiver, perhaps hundreds of miles away, they may be recognized as the voice of a friend?

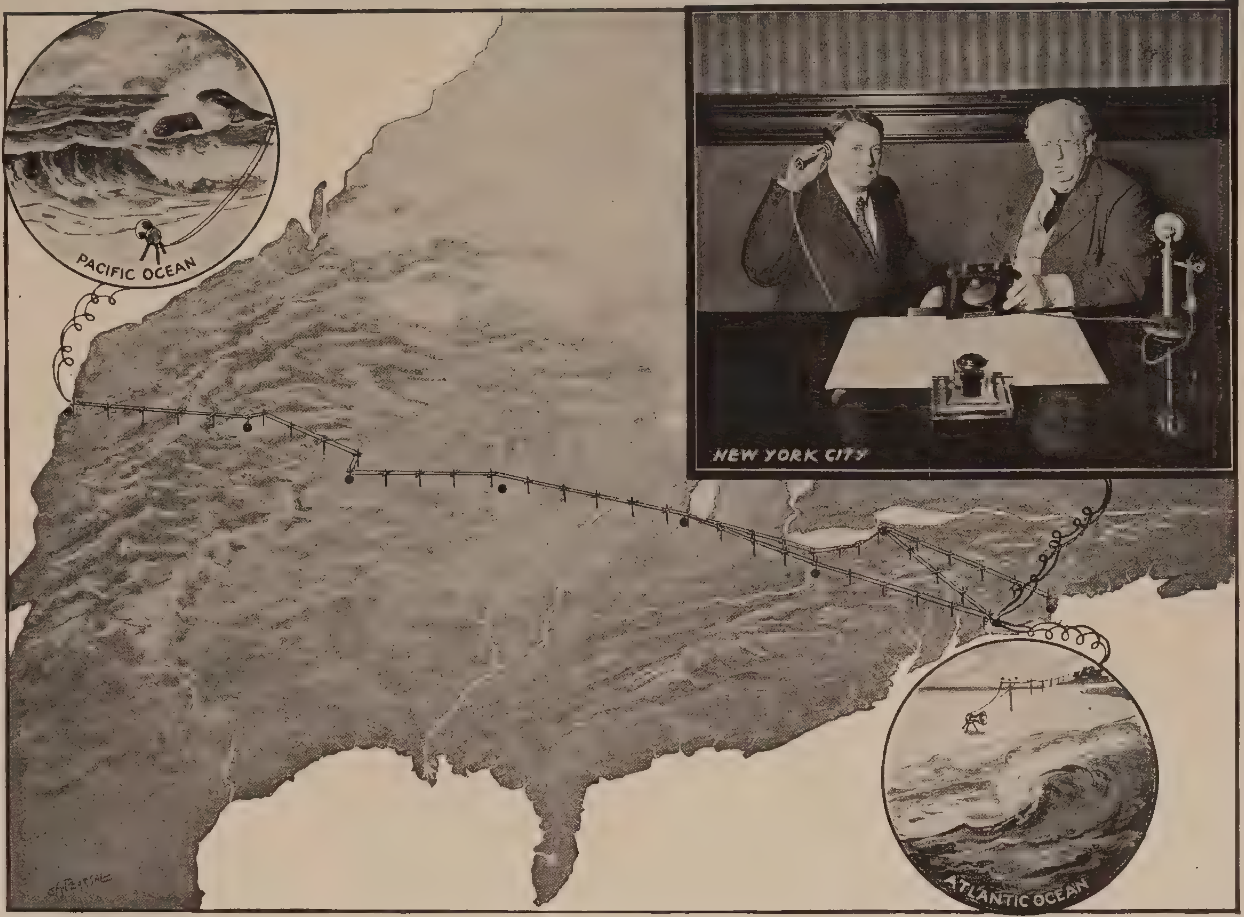
STRENGTHENING THE VIBRATIONS

Except in those telephones connected with the very largest exchanges, this transmitter and its battery and the complete circuit of electric waves are entirely within the house of the subscriber and the waves are transferred to the main line, very much strengthened by passing through an "induction coil," which is simply a coil made of two wires specially wrapped around a central core of iron. It is called an induction coil because a current passing through the first wire will induce in the second wire a like current, only stronger, so that it will carry farther. By using an induction coil in this way the vibrations will carry for hundreds of miles and will be much better adapted for practical use.

THE SIGNALING DEVICE

The next problem was to invent some signaling device by which subscribers might call one another. For this the simple expedient was adopted of introducing a lever which, when in

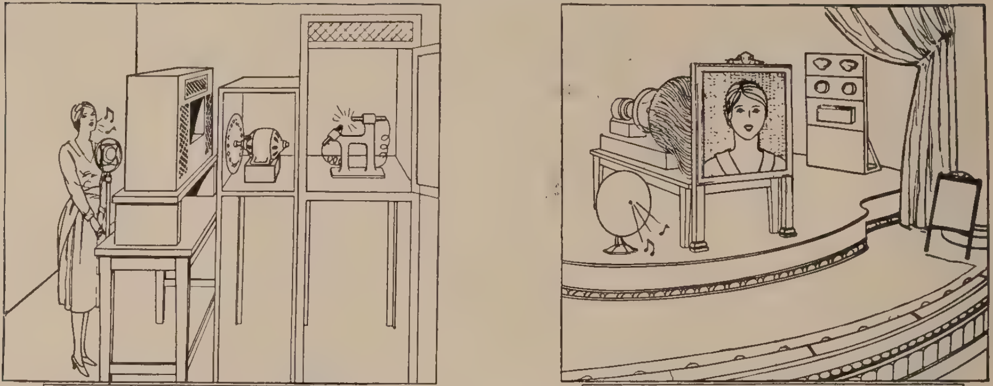
HEARING TWO OCEANS AT THE SAME TIME


PACIFIC OCEAN
NEW YORK CITY
ATLANTIC OCEAN

Courtesy *Electrical Experimenter*, N. Y.

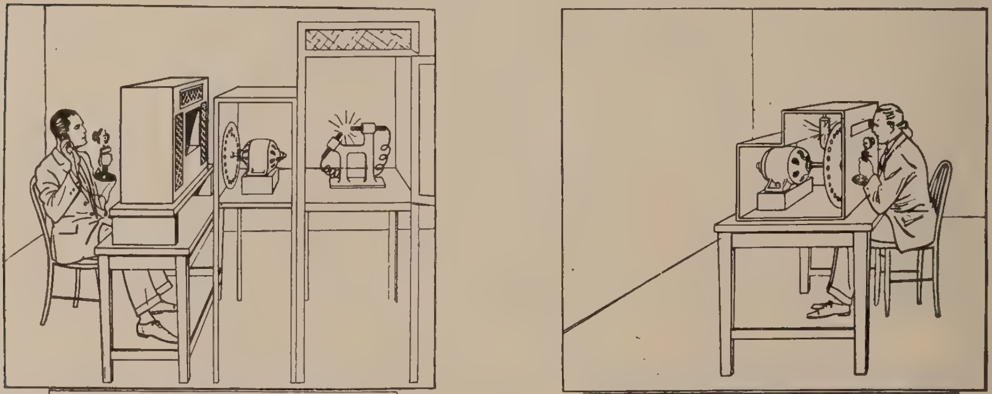
OVER A TELEPHONE LINE 3400 MILES LONG

A unique American method of entertaining distinguished guests from other lands.



SENDING APPARATUS AT WHIPPANY FOR TRANSMISSION BY RADIO

IMAGE BEING RECEIVED IN NEW YORK FROM DISTANT STATION BY AUDIENCE



SENDING APPARATUS AT WASHINGTON FOR TRANSMISSION BY WIRE

IMAGE BEING RECEIVED IN NEW YORK FROM DISTANT STATION BY INDIVIDUAL

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THE METHOD OF TELEVISION

This diagram shows the operation of the telephone service by means of which a person can talk over the telephone to a person in another city and not only be heard by him but see him and be seen by him as well.*

position with the receiver hanging on one end, breaks the telephone circuit but completes an ordinary push-button-and-bell circuit. When the receiver is lifted from the hook, a spring draws the lever upward, breaking the bell circuit and completing the telephone circuit. The necessary current for ringing the bell is obtained either by placing the push button and bell in circuit with the transmitter batteries or else by introducing a magneto-generator which rings the bell when the crank is turned. This latter method is used only in districts remote from the city exchanges.

In the largest telephone exchanges still further signaling improvements have been made. But before we can understand them, we must think of what is happening at "Central" while you are making your circuit and waiting for an answer.

THE TELEPHONE EXCHANGE

A central telephone exchange is a room to which all the telephone wires of a given locality run. There, by means of a switch, any one line may be placed in connection with any other line. The central exchange of one town is connected with that of another by one or more trunk lines, so that a subscriber may speak through an indefinite number of exchanges.

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* For "Television" see also Volume Ten, page 86.

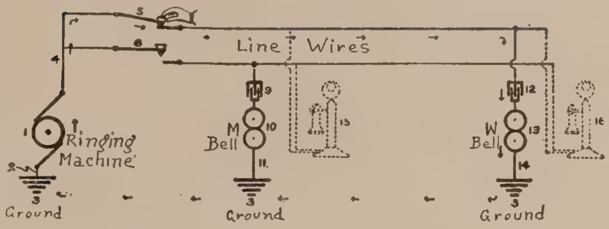


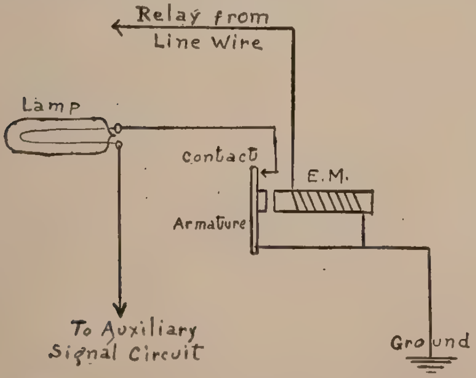
DIAGRAM OF CIRCUIT FOR DIVIDED RINGING

With the development of telephone improvements and service the central exchange has become an increasingly important center of the telephone activity of a given circuit. Not only are the actual connections made here, but to-day, in the most modern exchanges, there is one common battery, doing away entirely with the necessity of a local battery at each subscriber's station and thereby eliminating many "outside" troubles and vastly increasing the efficiency of the service.

WHEN YOU LIFT THE RECEIVER

When you lift the receiver you light a small lamp before the operator. Our first thought is of "Central" as a noisy place with dozens of telephones ringing all the time. As a matter of fact it is a comparatively quiet place, with only a low-toned droning sounding from all over the room, where long rows of girls are seated in front of switchboards, each with a receiver at her ear and a horn-shaped transmitter hanging before her mouth, and each saying, "Number, please?" "Line is busy," etc. This is because the girl's attention is called, not by a sound, but by the lighting of the little red lamp which is the signal for your line.

This lighting device was brought about by having the release of the receiver hook complete the circuit flowing through the central office and by introducing at the central office an electromagnet into the line. This magnet is set close to an armature which, when drawn toward the magnet, completes a small electric-light circuit, entirely independent of the telephone wires, lighting up the signal lamp.



METHOD BY WHICH LAMP IS LIGHTED AT EXCHANGE

Seeing the lamp lighted, the girl lifts a small plug from her desk and puts it into its proper hole in the switchboard. Then, by pressing a key, she gets a talking connection with you, and you hear the familiar words, "Number, please?" You give the number, she repeats it, returns her key to its place, lifts another plug and inserts it in the hole connecting with the person you have called. She has a ringing key which she presses to signal on the line you want. Your friend answers the ring by lifting his receiver and speaking.

Now you can see why the girl has the receiver hanging at her ear and the transmitter fixed in position before her mouth. Her hands must be free to work, and they do work, while her eyes are watching the flashing of colored lights before her.

After the conversation is finished both persons hang up their receivers, by that act lighting again the operator's lamp and showing her that the conversation is at an end. Then she returns the plugs to their original position. A complete telephone call is over, and, in spite of the swiftness with which it has been made, twenty distinct acts have been performed. In New York the average time for making a call is eleven seconds, a record which means that the girls have been trained for their work in schools of the company.

DIVIDED RINGING

One of the greatest improvements in telephone service from the householder's point of view is the system by which on a two-party line you are called only when your own number is wanted and need not know when the other person on the line is called up. This system of "divided ringing," as it is called, is made possible by running a third wire from one of the bell terminals to the ground. Then when "Central" makes her ringing contact she does not complete a circuit between the two line wires which would ring both bells, but between one line wire and the ground. As one line wire connects with one party's bell, and the other line wire with the other party's bell, it is evident that the bell which is rung depends upon which line wire "Central" connects to the ground. This is clearly illustrated in the drawings on page 59, as well as the method of lighting the lamp at the exchange.

THE AUTOMATIC TELEPHONE

The central operators at a telephone exchange are trained to great efficiency and make connections for us with much skill, accuracy, and rapidity; yet for all that the "human element" enters into the matter. The more people there are handling a message the more chances there are for mistakes, and inventors have devised several types of automatic switchboards and several styles of automatic telephones by which each subscriber serves as his or her own "Central," making connection without the help of a central operator.

In this type of telephone three or four numbered dials are so set that the figures opposite an indicator make up the number of the telephone being called; or possibly a single dial is turned first to the figure representing the hundreds unit, next to the tens unit, and finally to the last figure of the desired number. Then the bell on the line called begins to ring and the person with whom you wish to talk answers your call directly. In these types of telephones the original installation and equipment is more costly, extensive, and complicated than in the more common type, but this initial expense may be offset by the lesser cost of operation. They have been popular and successful in many smaller cities, and are now being installed as rapidly as expense will permit in many of our larger cities. This seems to be the service of the future.

SENDING PICTURES BY WIRE

The inventor of the telephone might have smiled at the prediction that some day pictures would be sent over telephone wires. Yet this seemingly miraculous feat is now being done as a matter of everyday business.

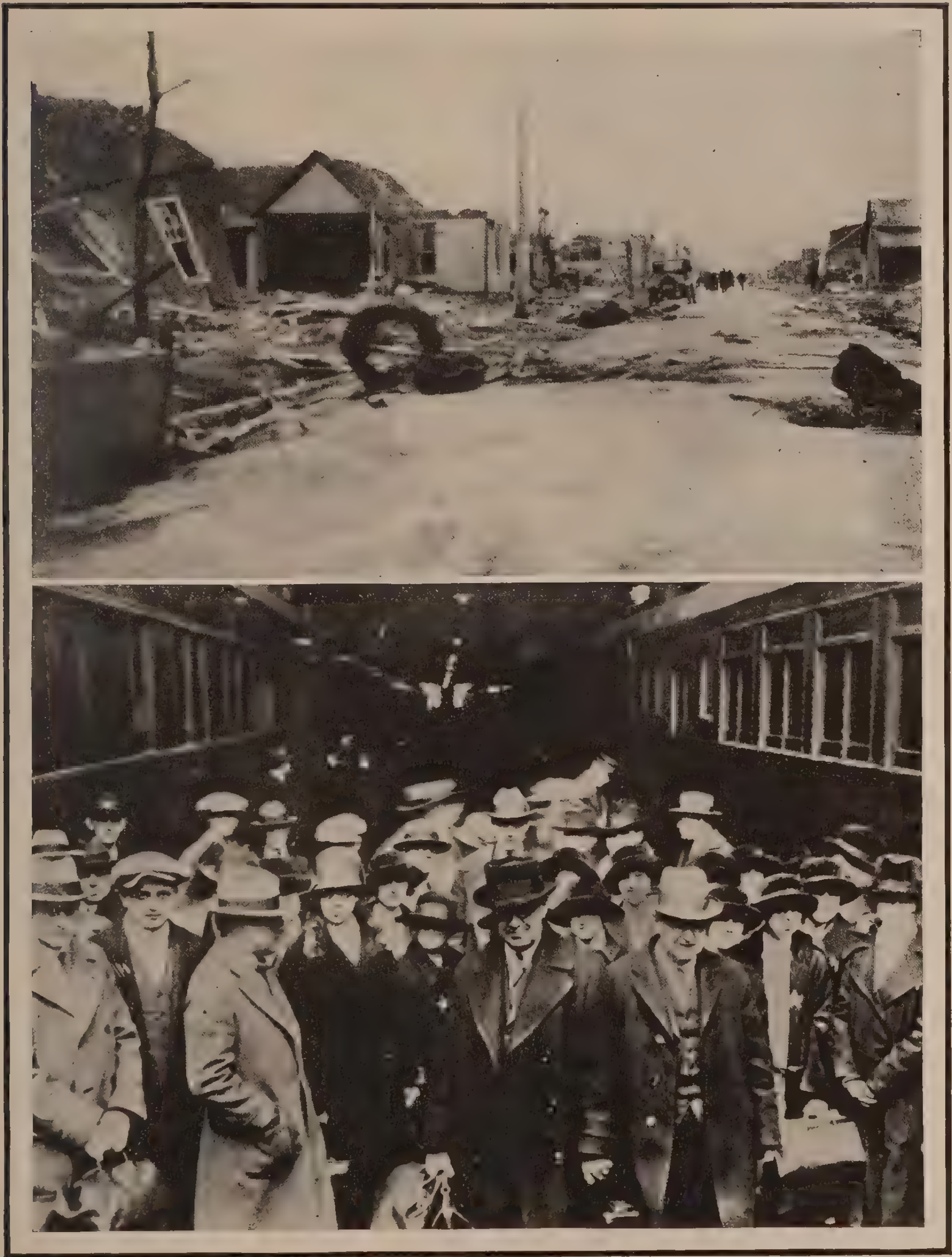
Nearly anything that can be photographed can be transmitted by wire. Just think of being able to send a picture, a signature, a printed page, or a finger print almost instantaneously to someone a hundred or a thousand miles away. Yet a post-card size photograph can be sent to any point in about seven minutes.

The picture to be transmitted is printed on a celluloid film, similar to the one used in your camera, which is wrapped around a transparent cylinder. Inside the cylinder is a photo-electric cell, a sort of vacuum tube which can vary the strength of an electric current according to variations in the brightness of a light which shines upon it.

A point of light is focussed on the transmitting cylinder, and passes through the film to the photo-electric cell. The cylinder turns slowly and moves along a little at the same time, so that the point of light gradually traces its way over the entire surface of the picture. More or less light is allowed to pass according to the shading of the film, which causes more or less current to pass through the photo-electric cell. This causes small electrical vibrations, which are amplified and sent over the wires to the receiving station.

There a sensitized celluloid film is wrapped about a receiving cylinder, which is moving at exactly the same speed as the cylinder at the sending station. A beam of light from a lamp passes through a light-valve and strikes the sensitive film. This valve is operated by the electrical vibrations coming over the wire, and allows varying amounts of light to reach the film. As the light makes its way across the film it reproduces every detail of the picture being sent. The "exposed" film is developed as in photography, then prints are made on photographic paper which are identical with the original picture miles away.

A similar method is also applied for the transmission of pictures by radio or over the telegraph wires.



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A NEW USE FOR THE TELEPHONE — PHOTOGRAPHS TRANSMITTED OVER ITS WIRES

These two photographs, showing conditions in the cyclone area in Indiana in 1925 (above) and doctors and nurses leaving Chicago on the first relief train (below), are the first news photographs sent over the telephone wires by the American Telegraph and Telephone Company. (See also page 220.)

Copyright, Underwood & Underwood

MARCONI, INVENTOR OF WIRELESS TELEGRAPHY

THE STORY OF RADIO

THE ends of the earth only half a second apart — that is the story of radio condensed into ten words. Of the "why" and "wherefore" of it, of the "how" and "when" of it, we shall speak in a moment. But the fact itself should first have its chance to grip our imaginations. Think how far apart the ends of the earth have been! how explorers and traders have sailed weary months and years with no news from home, no means of reporting their location or condition to the anxious watchers in the home lands! Think of those gallant missionaries of not more than a hundred years ago who bade farewell to the ship that brought them to some lonely Pacific island, knowing that it would be a full year before that vessel could possibly return with letters and newspapers from the land which they had left, and that when the news did reach them it would be six months old!

Compare this with the amazing situation in which Rear Admiral Byrd has found himself, separated from the populated areas of the world by hundreds of miles, in a region almost unattainable because of barriers of ice and snow, and yet able not only to report daily his experiences to listeners all over the globe, but also to get intimate and official messages from home.

The story of the progress of the world might be written in the terms of its means of communication from the days of watch fires on the mountains and of runners from village to village to the days of the written and the printed word. The tale would progress slowly with only moderate gains until the nineteenth century. Then would come the postal system, which brings every country of the globe within the reach of a letter with a five-cent stamp. Parallel in time with this wonderful gain would be the telegraph and cable systems of the globe, with millions of wires wrapped about the earth, carrying the code messages of dots and dashes which could be quickly translated into words. Our fathers and mothers thought themselves blessed beyond measure to be living in the age of the telephone, when codes and signs could be put aside and the actual sound of the human voice could be carried on wires from one end of a continent to another. Men will be living for many years to come who remember vividly the first uses of the telephone.

And then, almost overnight, as it seemed to the onlooker, came the marvel of communication without wires, the sending of messages through space. In a very real sense we of this particular period are seeing radio as no other generation in the world's history can ever see it. Everyone except our boys and girls has lived in a world where there was no wireless communication, where such a feat as having our messages leap instantaneously from spot to spot was unheard of. Radio jumped into everyday use with a rapidity never equalled in the practical application of any discovery during the world's history. Unknown in one year, the radio set became the tool and the toy of the civilized world in the next year. The men who did the first work with so-called "wireless" are not old men. Yet they with the rest of the world can sit in their homes and hear statesmen speak to them from overseas; they can pick up news by radio as they ride in their luxuriously equipped automobiles or airplanes.

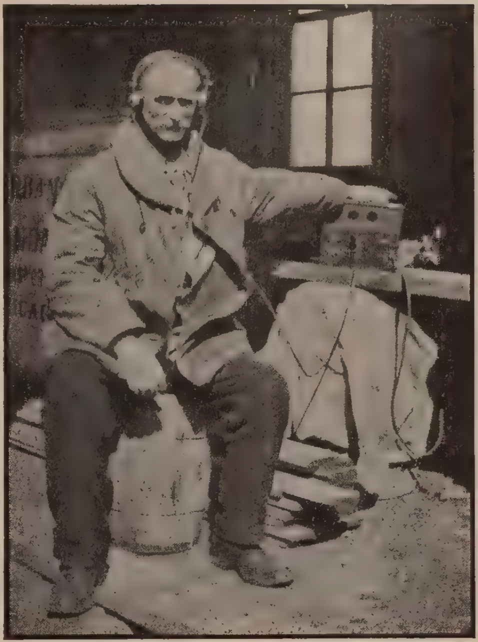
Our children take this talking without wires for granted. Even as the telephone is now a necessary and accepted convenience, so the bringing of distant corners of the earth into instantaneous communication seems so natural as to be commonplace. Only to us of this generation can the marvel, the miracle of radio, come home with full force. We have the background of having lived when it was unknown, and the foreground of its present widespread use. We can use both experience and imagination to look into the immediate and more distant future to see what a change in the world's development this new discovery will make.

THE THEORY OF RADIO

To those of us who have followed in these volumes the simple story of light and heat, the theory of radio need present no difficulties. In this more popular and general chapter we shall introduce the subject of radio. In Volume VII, pages 368 to 376, the subject of "Radio in Principle and Practice" is presented from the standpoint of the radio engineer, with a clear and understandable exposition of the manner and method of its use. We refer the reader to that chapter for information which we shall make no effort to present here.

In the story of "Messages from Other Worlds," Volume I, pages 93 to 105, we learned that heat and light come to us in waves through the invisible ether which, as it is assumed by modern science, probably fills all space. Waves set up in a vast ocean of ether by the sun and stars travel to us and make upon our bodies, our receiving apparatus, the effects which we translate into terms of light and heat. We learned of wave lengths how waves follow each other in processions but at different rates, with more space between the crests of certain types of waves than between the crests of other types. By wave length is meant the distance between two successive waves, the only difference in ether waves being in the rate at which they are made. All this is by way of review of our knowledge concerning these ether waves which we now meet again in connection with the subject of radio.

"Wireless," so called, or radio, is man's control of electromagnetic waves in ether. The sun sets up disturbances in ether or space; they travel earthward at the rate of so many vibrations per second and become perceptible to your senses through the medium of your eyes in the form of sunlight, or through the medium of your skin in the form of heat. You light a lamp; you are setting up waves in the ether which you will know as light. You start a fire in your stove; you are setting up electromagnetic waves which are at a lower rate of vibration than those of light and are perceived by you as heat. Light and heat are exactly the same thing — electromagnetic waves; the only difference is in the length of the waves. Wireless is exactly the same thing as light and heat. But while the wave lengths of light and heat are so short as to be at one end of the keyboard, with a measurement of a fifty-thousandth and a ten-thousandth of an inch, respectively, the wave lengths used for wireless communication are very long, perhaps from one hundred feet to twenty miles. Such waves



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ILLINOIS FARMER RECEIVING REPORTS OF GRAIN CROPS BY WIRELESS have been traveling about in space for all time. Disturbances in the ether which sent out waves of this length have been happening, unknown to or unmeasured by man, for countless ages. But man has only recently detected them, and still more recently learned to create and use them for his purposes of communication.

Copyright, International

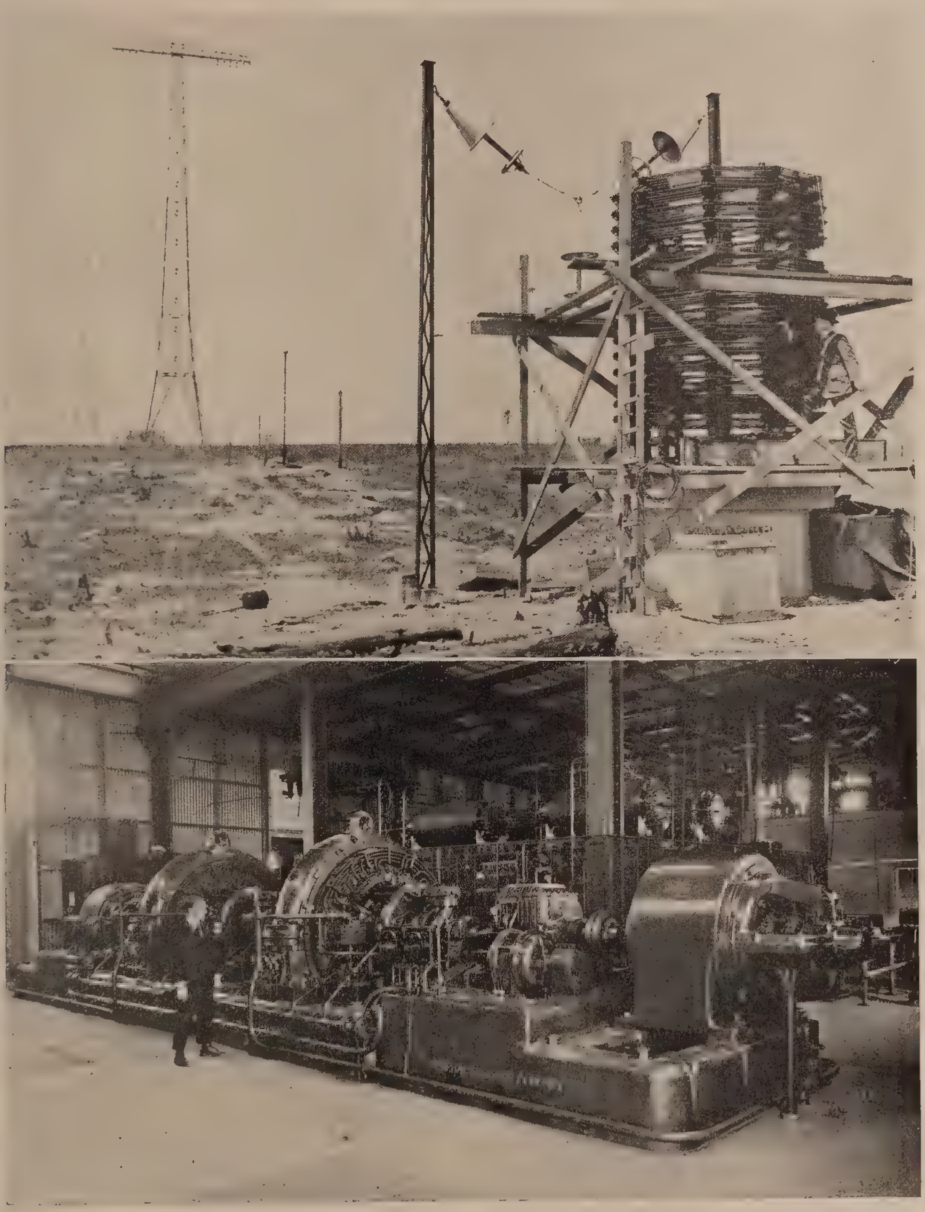
NEW YORK POLICE CAR

Equipped with radio receiving apparatus, and with a newly invented police automatic rifle, weighing but seven pounds and firing one hundred and twenty shots a minute.

THE FIRST USE OF WIRELESS BY MAN

Waves passing through the ether were first called "Hertzian waves," from the distinguished physicist Hertz, who discovered them. He, in his turn, was following out, as we are told in Volume VII, certain predictions and theories of the distinguished English physicist, Maxwell. Guglielmo Marconi applied these electric waves for the communication of signals through space, and is therefore often termed the inventor of wireless telegraphy. In other words, he was the first human being to practice the artificial creation of disturbances in space in such a manner that he could signal through space to a man at a distance from him. This is wireless communication as it was first practiced by him in 1896 and 1897 and as it is now practiced all over the earth. The theory has been so well summarized by a radio writer, French Strother, that we are going, at the risk of some repetition, to quote his words.

"The discovery of wireless, then, amounts to this: Man has discovered that he can artificially create disturbances in the ether which are periodic in character and of such great wave length that they can be distinguished (mechanically) above the multitude of shorter heat waves and light waves, and so he can



Photos, Radio Corporation of America

AT RADIO CENTRAL

Top: A Multiple Outdoor Tuning Inductance, showing the giant antennæ which stretch out over thousands of yards.
Bottom: The famous Alexanderson Alternator which has made trans-oceanic communication possible.

International Newsreel Photo

SMALLEST RADIO SET IN THE WORLD

Mounted on a ring and worn on the finger.

use them to signal to other men anywhere on the earth. In practice, this signaling takes the mechanical forms of reproducing human speech (the wireless telephone) or human rappings on a piece of metal (the wireless telegraph).

"The great variety of wave lengths that can be used in wireless is what gives it its vast possibilities for usefulness. These wave lengths vary in present practice from approximately two hundred feet up to twenty miles. By mechanical means too complicated for description here, men have been able to 'tune' their receiving instruments so that they will detect only the ether waves that are six hundred feet long or fifteen hundred feet long or two miles long, or whatever other length they may choose for the moment. By this tuning process, the 'wireless ear' becomes deaf to all other waves, even though myriads of other waves are at the same time disturbing space."

BROADCASTING

Following Marconi's discovery, the perfecting of radio instruments and the setting up of commercial and government wireless telegraph stations were gradually accomplished for a period of two decades or so. Before the year 1914 there were several transoceanic stations in operation, and a year later the American Telephone and Telegraph Company, working with the Western Electric Company, managed to transmit the human voice from Washington to Paris, a distance of thirty-seven hundred miles. Within the year the distance of five thousand miles, from Washington to Hawaii, was covered. These were spectacular feats of communication in their day.

Intense public interest in radio dates from the year 1921, when broadcasting from the radio telephone was begun at Pittsburgh, Pennsylvania. Broadcasting had been attempted before but without conspicuous success. Two inventors who were with the Westinghouse Company, R. C. Rypinski and Frank Conrad, were able to make this public service feasible for popular use. The idea caught the fancy of the American people. Newspapers, advertisers, government agencies, churches, clubs, and private parties took it up. Manufacturers of radio sets were swamped with orders. One firm found itself in a few months with fifteen million dollars' worth of unfilled orders on its books, and was obliged to give notice that it

International Newsreel Photo

A HOME-MADE RADIO SET

Antenna wires stretched on an old umbrella frame operate this crystal set.

would take no more orders until it had caught up with its list. Quick-witted amateurs and would-be inventors went to work on the problem of making their own receiving sets, with the result that every radio show has exhibitions of new and clever devices that bear witness to American inventive and mechanical skill.

The principle of broadcasting is simple. By the "universal wireless," or Marconi system of transmission, a powerful mechanical device, in connection with an electric current, sets up electromagnetic waves in space (or ether) of a certain fixed wave length. Signaling is managed by sending these waves out at intervals of time which produce the effect of the dots and dashes of the Morse telegraphic code, or, in the case of the radio telephone, of the modulations of the human voice. The waves thus started at the radio "central" go out *in every direction*, as the heat waves from a stove or the light waves from the sun go in every direction. Every message sent out by such a central is "broadcast," — that is, it is sent out into the ether in straight lines like the rays of the sun in every direction, and can therefore be picked up by any receiving instrument tuned to its length of vibration.

THE GROWTH OF BROADCASTING

While broadcasting may still be called a new art, it has so taken the public fancy that today several hundred stations, in the United States alone, put long daily programs on the air. There is hardly a moment of day or night when a turn of the dials on a receiving set will not intercept some interesting entertainment. Yet broadcasts now go far beyond the field of mere amusement. Talks on household arts are given for the housewife; the farmer learns the latest market prices for his produce. The business man tunes in on news "flashes" or hears the speeches of leaders in government and economics. The aviator receives reports on weather conditions, so necessary for safe flight.

The increase of power used in transmitting now allows effective broadcasting even during summer, a season which under earlier conditions produced generally poor reception.

Today many programs come to us over "chain" systems maintained by great broadcasting companies. A program given in a central studio is carried over telephone wires to a number of widely scattered radio stations from which it is sent into the air. By this means important events have been broadcast from seventy or more different stations at the same time, reaching listeners in every corner of the country.

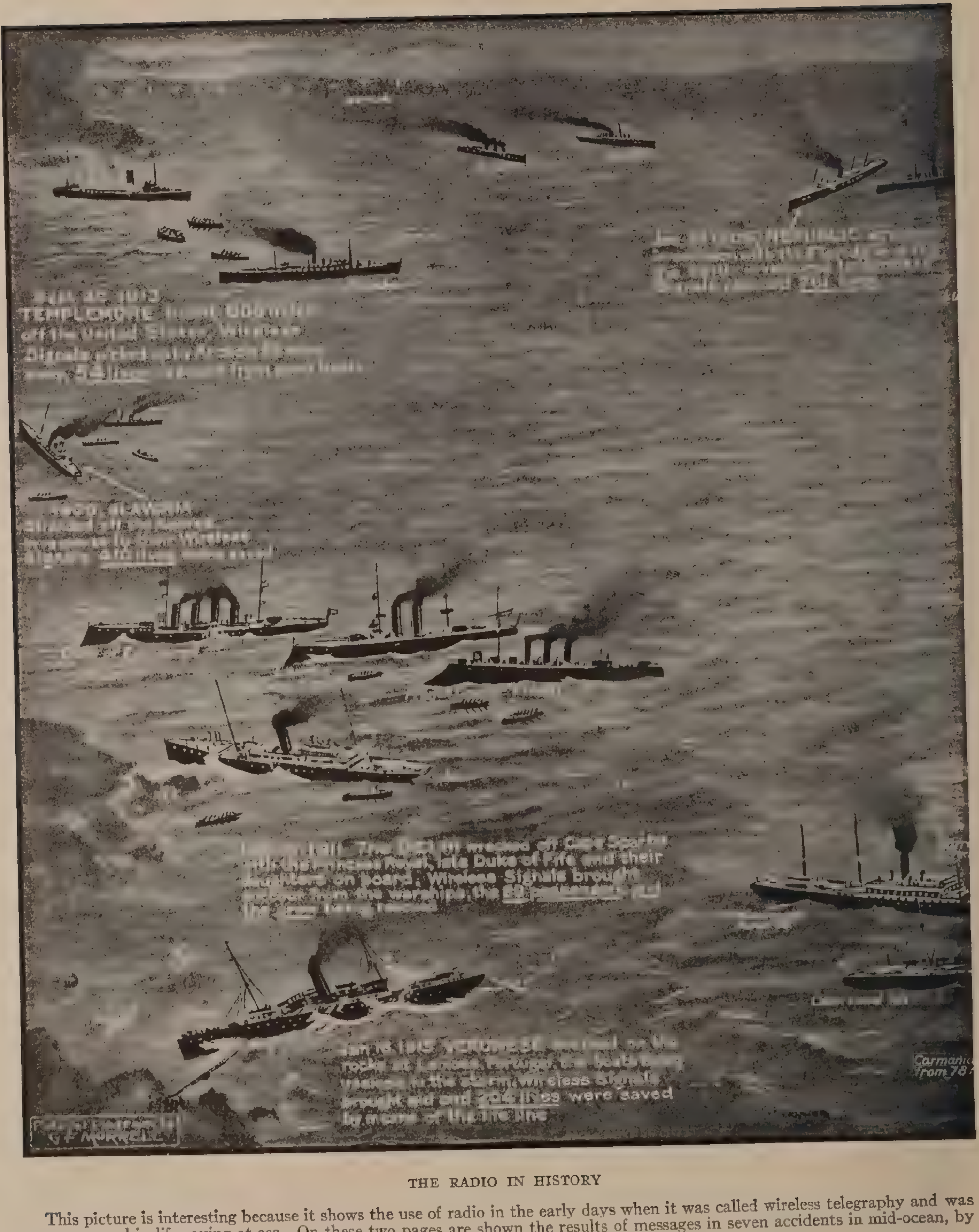
More recently, through the discovery that signals on short wave-lengths have unusual carrying power, has come an interesting exchange of broadcasts between nations. American programs have been received on several continents, while American listeners have enjoyed entertainment originating in England and Europe.

International Newsreel Photo

VEST POCKET RADIO SET

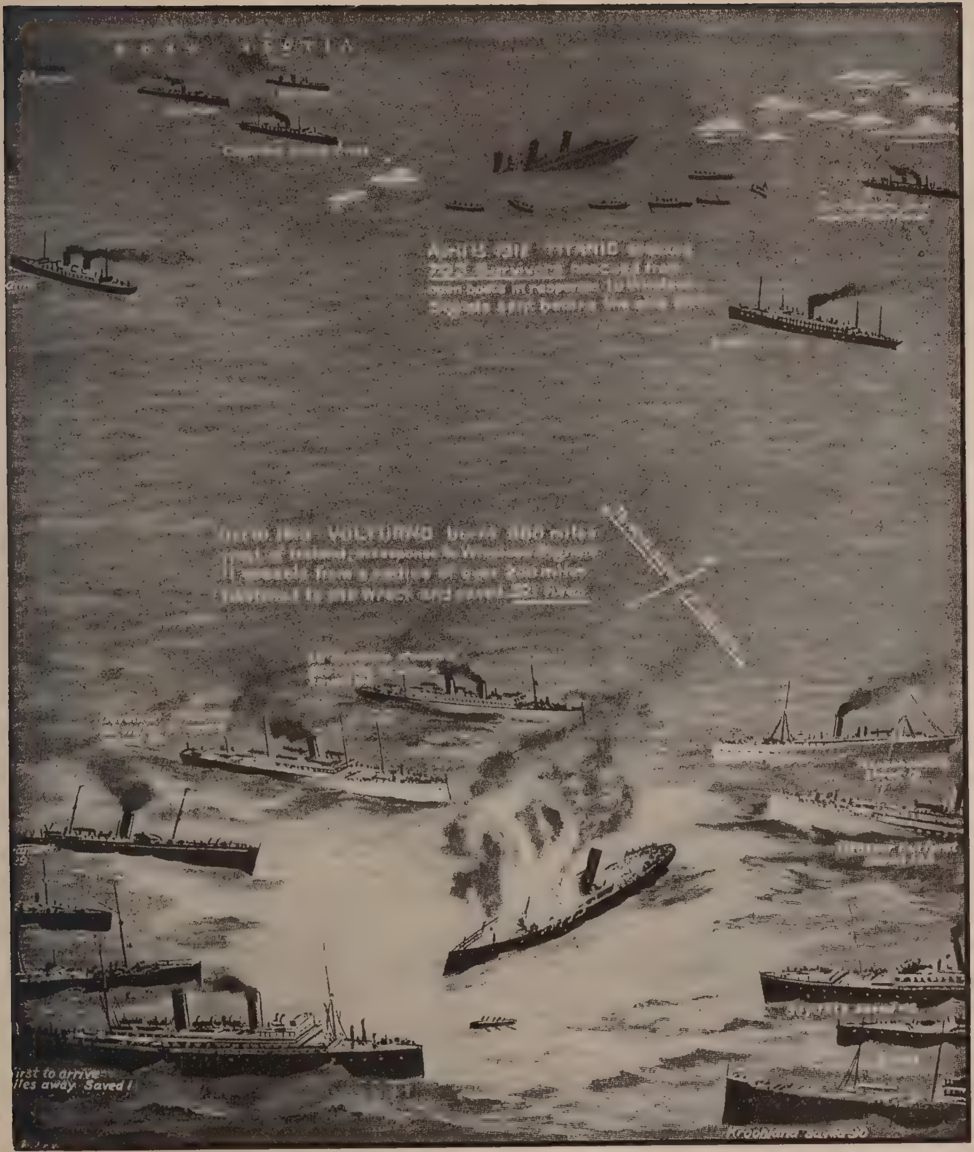
Made by a schoolboy; covers a radius of fifty miles.

In the space of a few short years, radio has grown from the stage of experiments into one of the country's leading industries, employing thousands in its factories and studios.



THE RADIO IN HISTORY

This picture is interesting because it shows the use of radio in the early days when it was called wireless telegraphy and was a new marvel in life-saving at sea. On these two pages are shown the results of messages in seven accidents in mid-ocean, by which at least twenty-eight hundred lives were saved that might otherwise have been lost.



MARVELS OF MARCONI IN MID-OCEAN

Vessels steamed from fifty-two to two hundred miles away to the assistance of these ships, sometimes one alone carrying off the survivors, or, in the case of the *Volturno*, eleven vessels coming within a few hours. All these accidents occurred in the Atlantic alone, where also many warnings have been given of derelicts, one of the greatest of sea perils.

REGULATING WIRELESS COMMUNICATION

Radio has come into use so rapidly that there are many problems still to be settled concerning its use. What could be permitted with only fifty thousand receiving sets in existence in the United States becomes impracticable when the number of sets runs up to several millions. "The use of the ether," we are warned by a radio expert, "is not limitless. It will accommodate just so many wireless messages and no more. When this limit is exceeded, chaotic conglomerations of sounds, which rival the busy day noises in a boiler factory, prohibit the sending or receiving of any kind of messages." Because chaos threatened the industry a conference was called in 1922 in Washington, at which radio experts from every branch of the service met to thrash out together the problems of the infant industry. All the agencies represented were unqualifiedly in favor of regulations which will be enacted by Congress from time to time as the situation develops. Certain wave lengths must be reserved for government use. Certain times should be set apart for business or official communication.

It is interesting to note that at this first radio conference President Hoover, then head of the Department of Commerce, under which much of radios' control has come, championed the cause of the American boy. He emphasized throughout the need for protecting the interests of amateurs. Should they be limited to too small a range of wave lengths or be cut off from the possibility of sending as well as receiving messages from a considerable distance, their healthy interest in the art would be unnecessarily quenched, and a great

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POLICE AUTOMOBILE EQUIPPED AS RADIO STATION

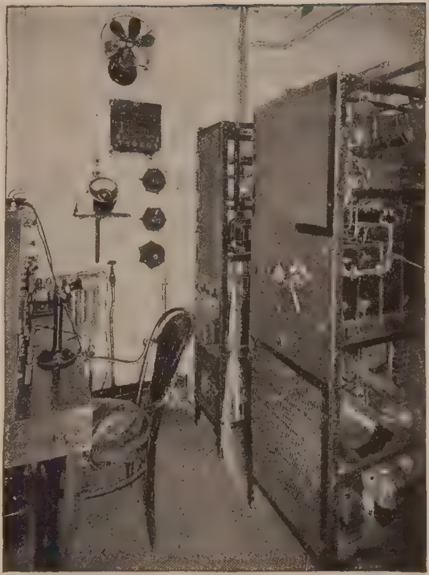
A flying squadron of police automobiles in Chicago can send as well as receive messages.

asset in the national development of radio would be lost.

The country is at present divided into districts, and every amateur setting up or desirous of setting up a transmitting set should apply for an operator's license to the radio inspector of his district. For information as to the districts, he should write to the Superintendent of Documents, Government Printing Office, Washington, D. C. He can also obtain from the Superintendent at a small cost a list of the "Amateur Radio Stations of the United States," published in book form. There are also national radio organizations with which he can get in touch. Non-professionals have done remarkable things in radio with machinery so simple and inexpensive that the big commercial plants have looked on in astonishment. This is a field in which any operator of inventive turn of mind may find his chance to do something original.

RADIO COMPASS SERVICE

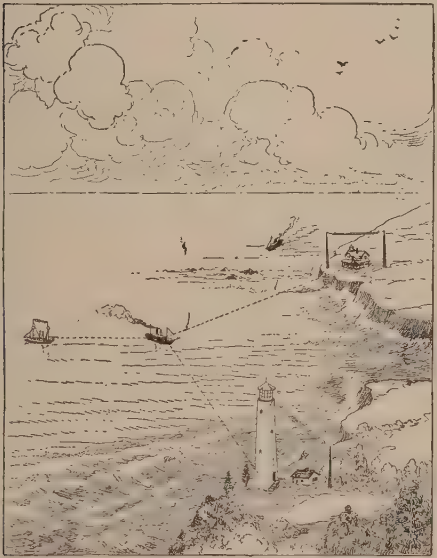
Radio compass service is an interesting branch of the work. A ship at sea sends out the question, "Where am I?" Suppose this ship is in the Atlantic, fifteen hundred miles off the coast. Boston picks up the question at its naval station and notes the direction from which the inquiry comes. New York gets the same inquiry, but from a different angle. Boston and New York get into touch with each other, compare their findings, and by a simple process of mathematical computation, draw the mental triangle which will enable them to determine from what point the signal came. One of the stations then signals the vessel its latitude and longitude. Wireless "lighthouses," so called, are being established along the coasts which will send out, at intervals as regular as the flashing of a light, signals which will be received by wireless sets at sea. The ship operator can locate the station by its own peculiar signal, can note the direction from which it comes, and can do his own problem of locating himself as at the third point of a triangle with two stations at the other two angles, by a comparatively simple mathematical process.



Courtesy of General Electric

SHIP TO SHORE TELEPHONE

The ocean traveler can step into a telephone booth like this and talk with his home office by radio.



Courtesy of Pacific Radio Publishing Co.

SHIP'S POSITION DETERMINED BY RADIO COMPASS

Direction finders are on the ship or at the shore radio beacons.

Copyright, Wide World Photos

THE OLD WAY AND THE NEW

President Hoover *writes* messages to the people of the United States, according to the old way; but he also speaks through the radio microphone to millions.

TODAY AND TOMORROW

Airplanes are being equipped with radio. A mission board in this country has recently decided to equip its missionaries in remote and isolated provinces of China with both airplane and radio service. Explorers carry with them their radio sets and will thus be enabled to keep in some touch with the world, and also to report any misfortunes which befall them, so that assistance may be promptly sent. Photographs have been sent by radio. The prediction is made that motion pictures will soon be sent by wireless. Already small ships and land vehicles have been controlled by radio,— that is, operated without hands by the directing power of a radio set which did not come into any actual physical contact with them. Nikola Tesla said not long ago that within twenty-five years crewless ships would find their way between the ports of the world guided only by the invisible arm of radio. The radio torpedo is already a dangerous instrument of war. Airplane patrols with radio equipment are saving millions of dollars by reporting forest fires so promptly that they can be fought before they get too great headway. So the story might be continued indefinitely.

"Radio," it has been well said,[1] "forms an invisible bond between the nations of the world. Indeed, it is a great and powerful binder of the peoples of the earth. An ocean cable runs from one landing place to another. It can easily be cut in times of war, and if it is not cut the impulses passing over it can be censored by its owners or by those who happen to be in command of the ports at which it terminates. Invisible radio waves pouring over the face of the earth cannot be cut. It is humanly impossible to interfere with them in the slightest way. When a radio message is sent it may reach all parts of the world . . . As Ernest F. W. Alexanderson of the Radio Corporation of America has aptly declared, 'It is not an exaggeration to say that the emancipation of the human spirit was begun with the invention of the printing press and has found its fulfilment in radio communications.'"

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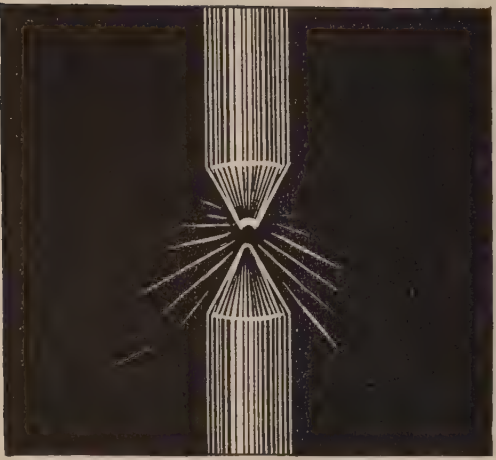
[1] The Complete Radio Book. The Century Company.

Copyright, International

AT THE OPENING OF NEW YORK LONDON RADIO-TELEPHONE SERVICE

President Gifford of the American Telephone and Telegraph Company is putting in the first transoceanic call, while a group of officials "listen in." Sir Evelyn Murray, Secretary of the General Post Office of Great Britain, received this call at the other end and replied.



CARBONS OF AN ARC LIGHT

HOW ELECTRICITY PRODUCES LIGHT

IT is not possible to state when the thought of producing light from electricity first started. It was discovered many ages ago that when certain materials were rubbed together something happened which produced sparks, and it may be that the first thought-seeds of the future brilliant illuminations were planted here.

THE ARC LIGHT

If two pointed pieces of carbon, each of which is connected to a terminal of a battery or other source of electricity, are brought into contact and then separated, an electric flame or arc will appear between the separated points and the points themselves will become white-hot. This intense heat vaporizes the carbon and a stream of carbon vapor is continually passing between the points. This vapor is a poor conductor of electricity, so that while the current will pass through it, yet the resistance to the electric flow causes the vapor particles to be heated to the point of incandescence and they give off light. The white-hot carbon points, however, emit much more light than the heated vapor. These facts were discovered by Sir Humphry Davy in 1800, and he constructed the first arc light.

It is interesting to note that no current will flow and no light will appear until the carbons have been brought into actual contact and the flow of carbon vapor established. As the carbons are vaporized, it is necessary to keep moving them nearer together to prevent the intervening distance from becoming too great.

The modern arc light is simply a machine for steadily feeding the carbons together as they are eaten away by vaporization, after first starting or "striking" the arc. The "hissing" of an arc light indicates that the points are too near together; flashing and spluttering show that the distance between is too great. In the perfected arc lights of to-day, however, the feeding is very regular and steady. The brilliancy of the arc makes it one which may be used where the light must carry for long distances, as in lighthouses, searchlights, etc.

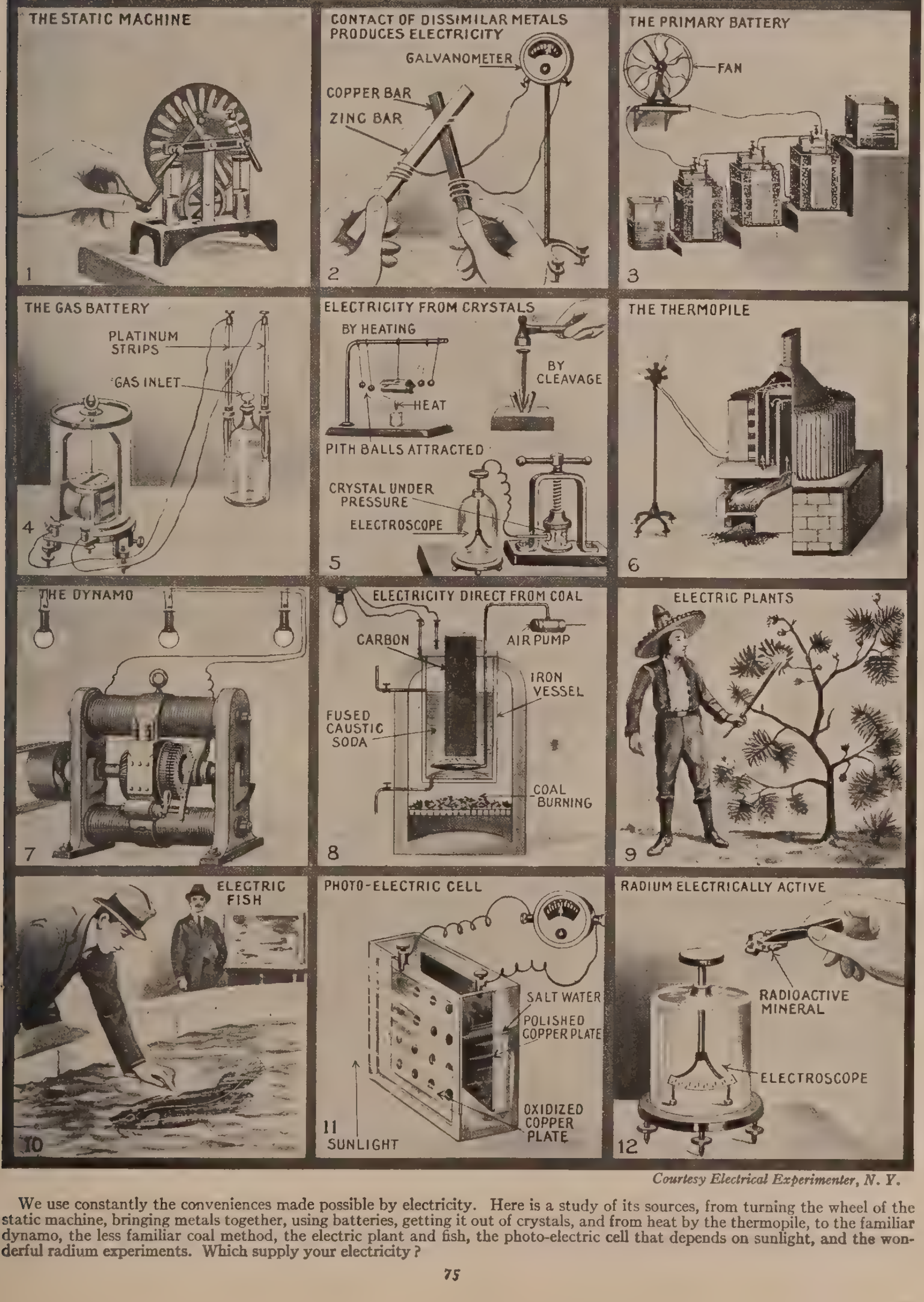
The shape which the carbons assume as they vaporize is clearly shown in the illustration. The greatest amount of light comes from the upper carbon with the concave end.

THE INCANDESCENT LIGHT

If we pass a current of electricity through a carbon "wire," the carbon offers so much resistance to the current that it glows, red-hot. If this carbon is in the open air, it will burn and break the circuit; but if it is in a bulb of glass from which the air has been exhausted, it will glow a long time before becoming useless. Thus we have the incandescent light as commonly used until recently, when new filaments have been devised to take the place of the carbon and give a much superior light at less cost. In these the filaments are composed of rare metals, such as tungsten, but the principle involved is exactly the same. In the lighting of houses, stores, public buildings, and streets, the incandescent light has of late largely taken the place of the arc because of its low cost and superior convenience. While the electricity for electric lights may be that from a battery, in practice it is found far cheaper and more convenient to use the current produced by a dynamo.

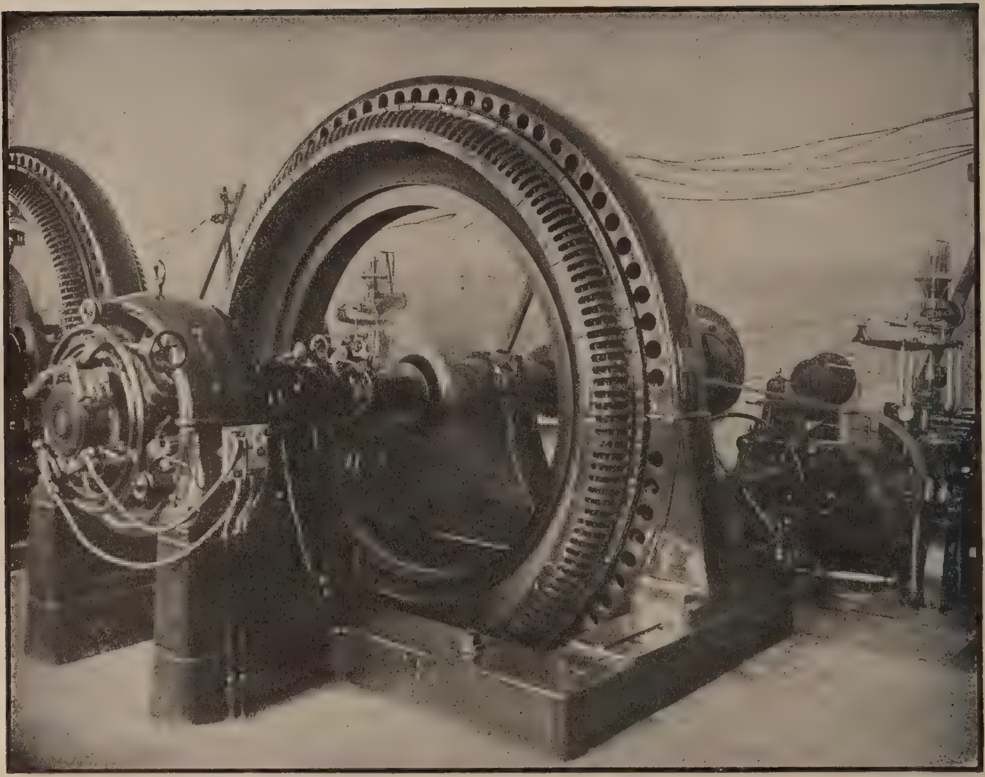
Of the two kinds of currents described in the following chapter, the direct was formerly used for incandescent lighting. At present, however, the simplicity of the alternating-current dynamo has made it the one most commonly used.

SOURCES OF ELECTRICITY


THE STATIC MACHINE
1
CONTACT OF DISSIMILAR METALS PRODUCES ELECTRICITY
GALVANOMETER
COPPER BAR
ZINC BAR
2
THE PRIMARY BATTERY
FAN
3
THE GAS BATTERY
PLATINUM STRIPS
GAS INLET
4
ELECTRICITY FROM CRYSTALS
BY HEATING
HEAT
PITH BALLS ATTRACTED
BY CLEAVAGE
CRYSTAL UNDER PRESSURE
ELECTROSCOPE
5
THE THERMOPILE
6
THE DYNAMO
7
ELECTRICITY DIRECT FROM COAL
CARBON
AIR PUMP
IRON VESSEL
FUSED CAUSTIC SODA
COAL BURNING
8
ELECTRIC PLANTS
9
ELECTRIC FISH
10
PHOTO-ELECTRIC CELL
SALT WATER
POLISHED COPPER PLATE
OXIDIZED COPPER PLATE
SUNLIGHT
11
RADIUM ELECTRICALLY ACTIVE
RADIOACTIVE MINERAL
ELECTROSCOPE
12

Courtesy Electrical Experimenter, N. Y.

We use constantly the conveniences made possible by electricity. Here is a study of its sources, from turning the wheel of the static machine, bringing metals together, using batteries, getting it out of crystals, and from heat by the thermopile, to the familiar dynamo, the less familiar coal method, the electric plant and fish, the photo-electric cell that depends on sunlight, and the wonderful radium experiments. Which supply your electricity?



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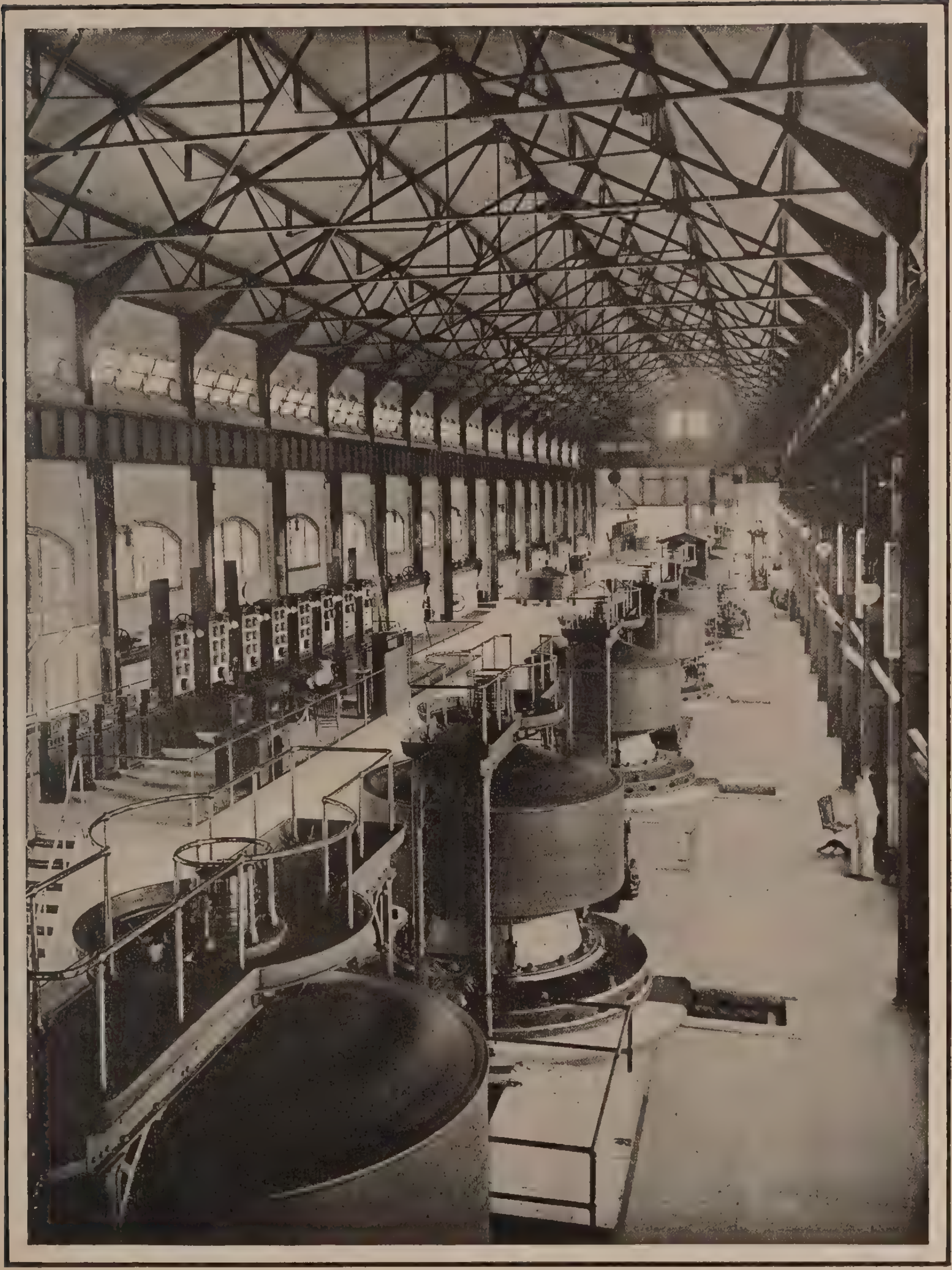
A LARGE DYNAMO

ELECTRICITY TURNED TO POWER

IN the world of electricity it is the dynamo that does the work. It is one of the great laws of the universe that energy cannot be destroyed. If it is supplied for use in one form, the exact equivalent always appears in some other form or forms. There is no more interesting illustration of this law than in the generation and use of electricity. The little whirling machine called the "dynamo" takes its power from a steam engine or a water wheel or some other similar source, which makes its parts revolve. Electricity so generated may then be carried an unlimited distance along insulated copper wires to another machine, similar in construction to a dynamo, but which changes the electricity back into mechanical power. It moves trains, turns mill wheels, and uses in a hundred ways the power which has been generated at the other end of the wire.

THE LAW OF THE DYNAMO

It is a well-known fact that a certain invisible influence exists around the ends of the poles of a magnet. If these two poles are brought near each other, the space between them is affected by both. This influence is spoken of as "invisible lines of force" which are imagined as passing from one pole to another. It is also called a "magnetic field." If a coil of wire is connected with an instrument which indicates the presence of an electric current and is moved through this magnetic field, an electric current will pass through the wire while it is moving across the lines of force. This fact was discovered by the British scientist Faraday in



Copyright, Underwood & Underwood

DYNAMOS IN NIAGARA FALLS POWER COMPANY PLANT

Each dynamo is of 5000 horse power and runs at a speed of 1500 revolutions a minute, producing a current of 2200 volts.

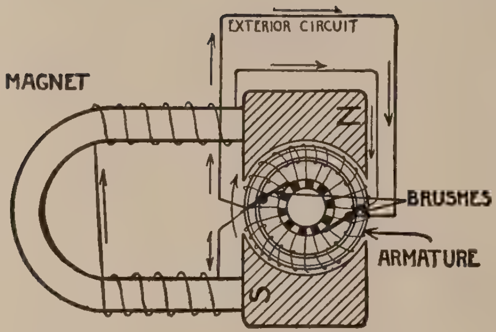


DIAGRAM OF A SIMPLE DIRECT-CURRENT DYNAMO

1831. It was found that only while the wire was in motion was the current present. The next step was to mount the coil of wire on a spindle and keep it rotating in a magnetic field. The motion was thus made continuous and a steady current generated.

THE DYNAMO

By winding a large number of coils on one spindle and driving the spindle by an engine at high speed, this tiny machine for generating electricity was enlarged into what was the beginning of the dynamo-electric machine, or "dynamo," a word derived from the Greek word for "power." The first of these machines was constructed by Faraday in 1832.

In order to collect the current thus generated, two copper rings were attached to the revolving spindle, one being insulated from it, and the ends of the coils were connected each to one of the rings. Two flat pieces of copper or carbon called "brushes" rested against the rings as they turned with the spindle, and the two ends of the external circuit were connected to these brushes. As this collection of wire coils, called an "armature," rotates between the magnet poles, each coil will pass through the lines of force twice in every revolution, the first time moving in one direction and the second in the opposite, and between these passages the coil will pass out of the influence of the field. This will cause the generation of two complete currents for each revolution of the coil, and these two currents will flow in opposite directions. There results in the external circuit, not a continuous current, but in reality a series of current pulses, alternating in direction. This is the principle of the alternating current. In an armature where there is a large number of coils, the number of changes or pulses of the current will depend on the number of the coils and on the speed of rotation.

THE ELECTROMAGNET

It was soon found that the permanent steel magnet would not furnish a sufficiently strong field to produce a current of any considerable commercial value. It was also discovered that if a piece of soft iron was surrounded by a coil of insulated wire containing an electric current, the soft iron would become to all intents and purposes a magnet as long as the current was in motion, and no longer. Furthermore, the strength of the magnetic field increased as the current sent into it increased. Here we have the electromagnet, which is used in all dynamos of to-day.

While the alternating current could be used for many purposes, experience proved that it would be an advantage to have a current flowing continuously in one direction. A continuous-current or direct-current dynamo was accordingly evolved. This in reality produces an alternating current which, when it leaves the armature coils, is changed into a direct current. To accomplish this the brushes are set, not in contact with rings connected directly to the coils, but with a commutator consisting of a number of copper bars insulated one from the other and connected with the armature coil at regular intervals. These connections are so

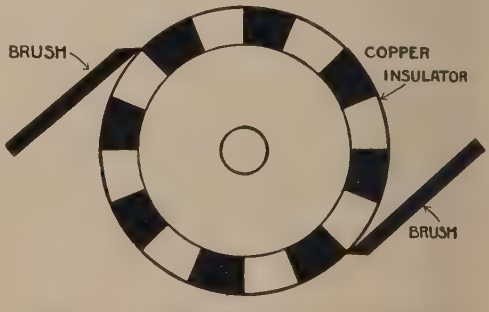
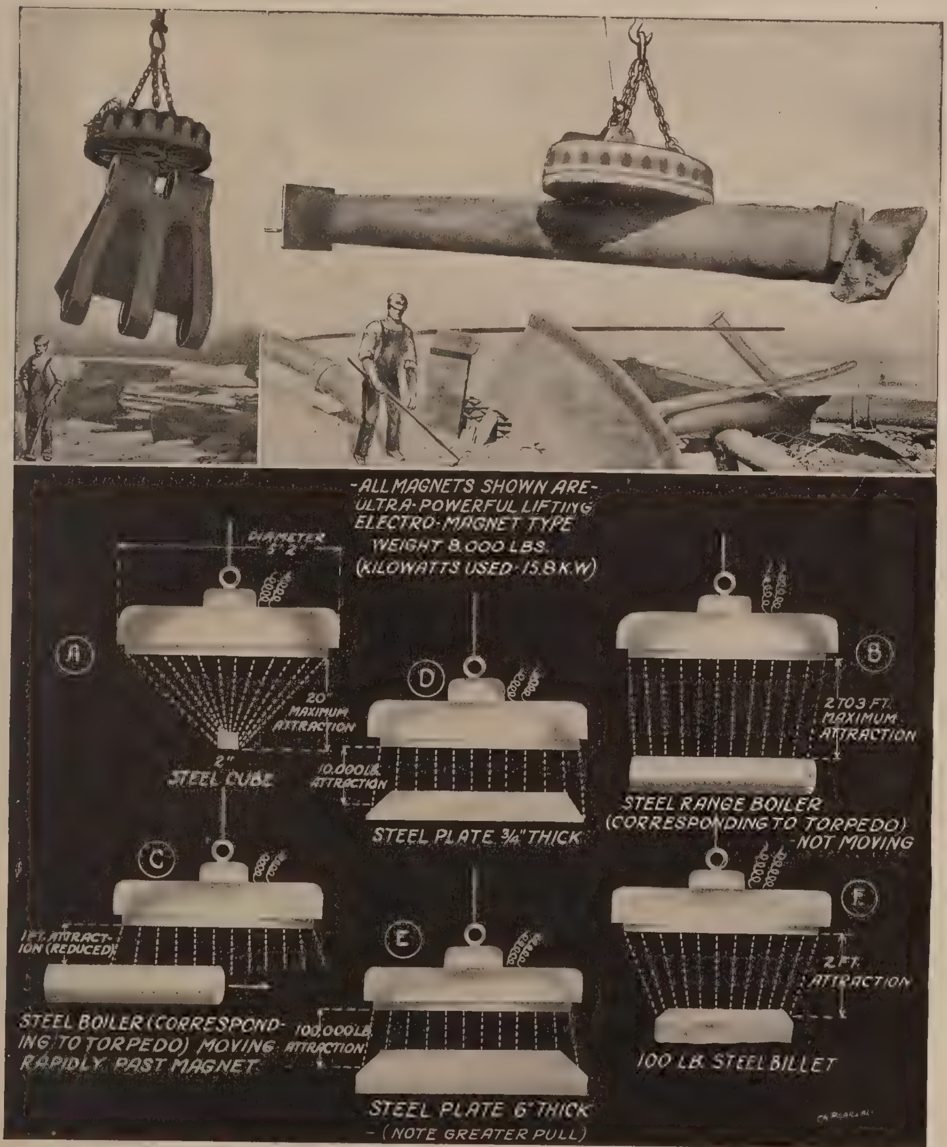


DIAGRAM OF A COMMUTATOR FOR A DIRECT-CURRENT DYNAMO

ELECTROMAGNETS LIFTING TWENTY AND THIRTY TONS


-ALL MAGNETS SHOWN ARE-
ULTRA-POWERFUL LIFTING
ELECTRO-MAGNET TYPE
WEIGHT 8.000 LBS.
(KILOWATTS USED-15.8 K.W)
DIAMETER
A
20" MAXIMUM ATTRACTION
2" STEEL CUBE
D
10.000 LB. ATTRACTION
STEEL PLATE 3/4" THICK
B
2 TO 3 FT. MAXIMUM ATTRACTION
STEEL RANGE BOILER (CORRESPONDING TO TORPEDO) -NOT MOVING
C
1 FT. ATTRACTION (REDUCED)
STEEL BOILER (CORRESPONDING TO TORPEDO) MOVING RAPIDLY PAST MAGNET
E
100,000 LB. ATTRACTION
STEEL PLATE 6" THICK
-(NOTE GREATER PULL)
F
2 FT. ATTRACTION
100 LB. STEEL BILLET

Courtesy Electrical Experimenter, N. Y.

HARNESSING THE WONDERFUL FORCE OF MAGNETISM

The electromagnet can attract only a comparatively short distance, but it can do wonders when it is set at work.

made that the current leaving the armature and passing through the commutator against which the brushes rest is delivered to these brushes as a continuous current and not as a series of alternating pulses.

Thus far dynamos have been spoken of as having a fixed magnetic field and a rotating armature in which the current is induced; but these may be reversed, and so we have some dynamos in which the electromagnets form the moving part, the armature coils being stationary. On these simple principles rests the generation of electricity, which, transformed into power, is doing to-day a large part of the work of the world.

ELECTROPLATING

Among a thousand minor inventions which have come from the use of electricity is electroplating. This is the covering of some baser metal, as german silver, with a thin film of silver or gold. It may be done with current supplied by a battery or by using the direct current from a dynamo. The article to be coated is suspended in a chemical solution of the metal to be deposited.

If the plating is to be silver, a plate of metallic silver is hung in the solution, together with a metallic bar from which are suspended the articles to be coated. One of the wires from the source of the current is attached to the metallic plate and the other to the suspended articles. The passage of the current causes the metallic silver to be deposited on the immersed pieces. In coating some metals, such as pewter or iron, with silver or nickel, they are usually first copper coated, as this metal will cause a better union to be made between the metals.

NIAGARA IN HARNESS

Of course a dynamo driven by a steam engine gives out no more power than the engine produces. Indeed, some power is lost in transmission. The dynamo and the electric motor simply make the use of the power more convenient, for between the two it may be carried miles on a slender wire.

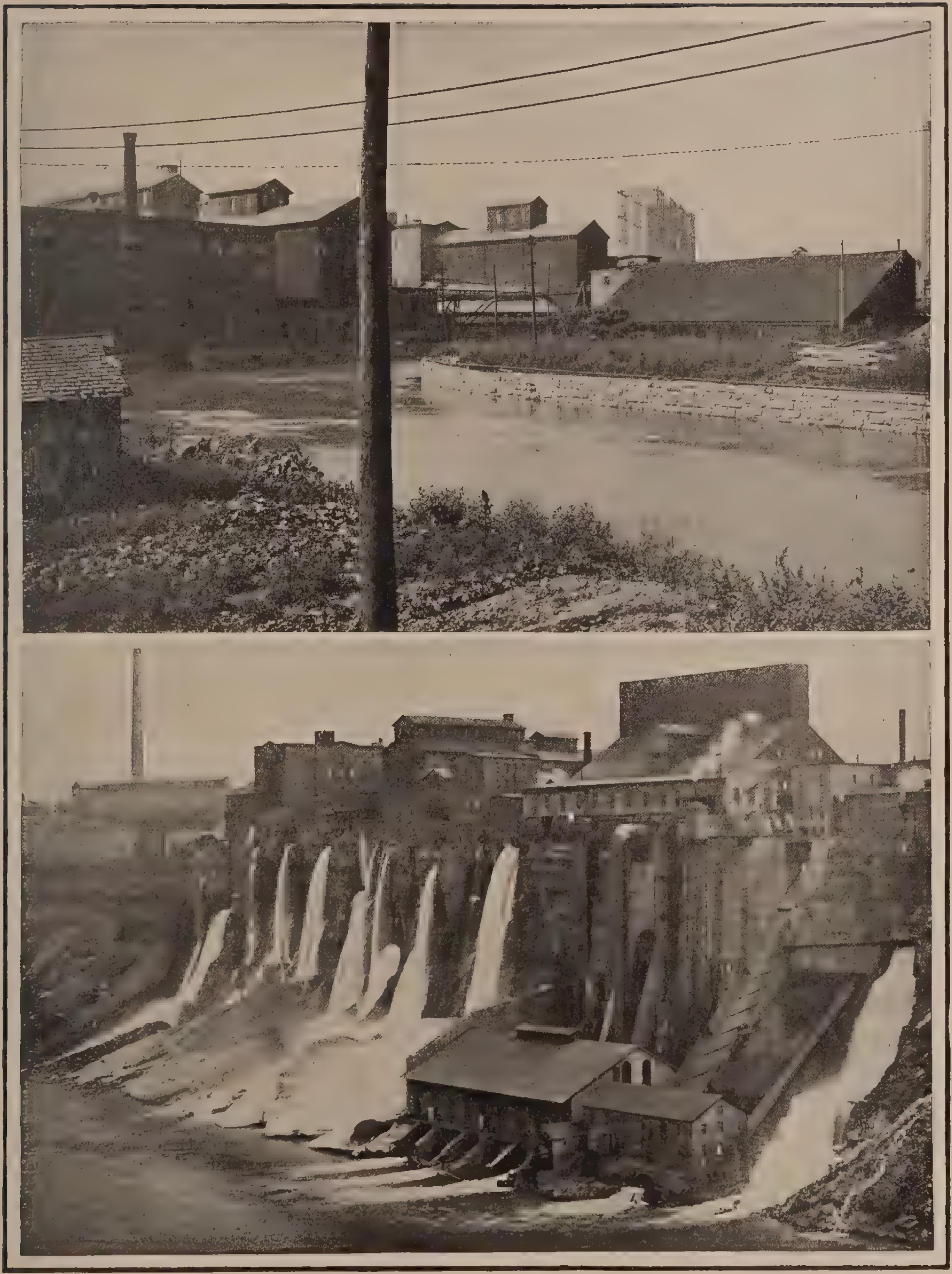
Falling water, by means of turbines (already described), produces power which is continuous and very cheap. Now that the dynamo permits us to transmit this power to a distance, water power is again beginning to take its place in the doing of the world's work, a place which it lost in part when steam came into use.

One of the greatest opportunities for using the power of falling water in the United States is at Niagara Falls on the Niagara River. Through this river passes practically all of the water from the Great Lakes, which have a total surface area of one hundred thousand square miles. Eighteen million cubic feet a second flow over the Falls, making a single drop of about one hundred and sixty feet. This is equivalent to nine million horse power, of which approximately five and one half millions are available for use. The present power equipment, established and building, is nearly three quarters of a million horse power.

By tapping the river one and a half miles above the Falls, the water is led through a tunnel twenty feet square to pits situated below the Falls, giving a total drop of two hundred feet, of which about one hundred and forty is available. These pits are one hundred and sixty feet deep, and at the bottom of each is placed a five-thousand-horse-power water turbine mounted on a vertical shaft which extends upward the whole depth of the pit, the dynamo being situated at the upper end. The heavy weight necessarily bearing on the foundation of this vertical shaft is ingeniously carried by a water cushion.

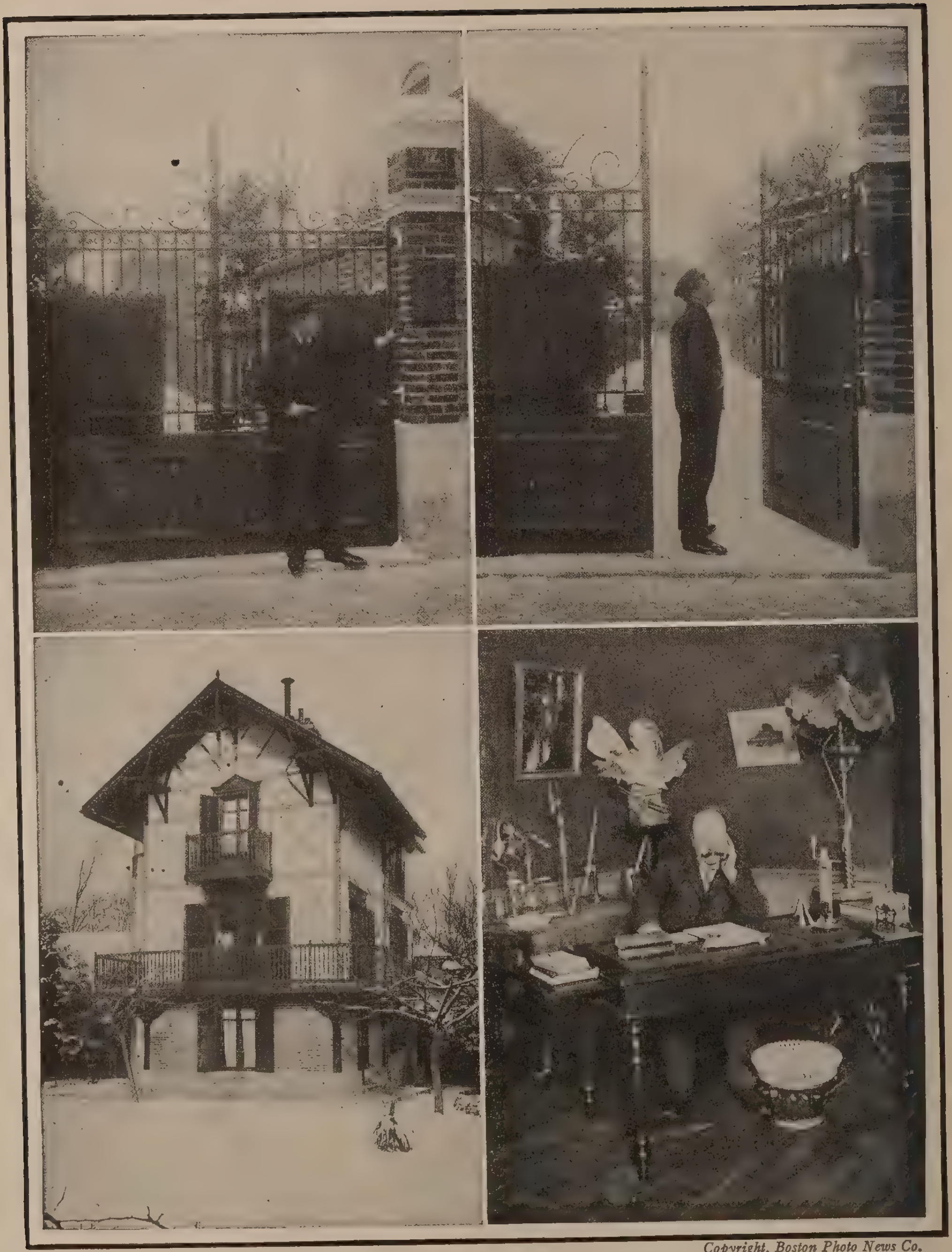
The development of the power on the Canadian side of the river will bring the grand total horse power up to between two and three million. This current will be distributed at Toronto, about sixty-five miles distant. A great deal of the electricity now generated at Niagara is used at Buffalo for lighting, street railways, and manufacturing purposes.

The great power station at the Falls has been the cause of the establishing of many manufacturing plants in that vicinity, all taking this power from the central station. The development which seems possible in the coming years bids fair to make this locality a leading one in the manufacturing world. Care is being taken, however, not to mar the grandeur of the Falls by directing too much of the water through the mill flumes.



POWER PLANT ON AMERICAN SIDE OF NIAGARA FALLS

Top: The rear of the plant. Bottom: The plant on the river side.



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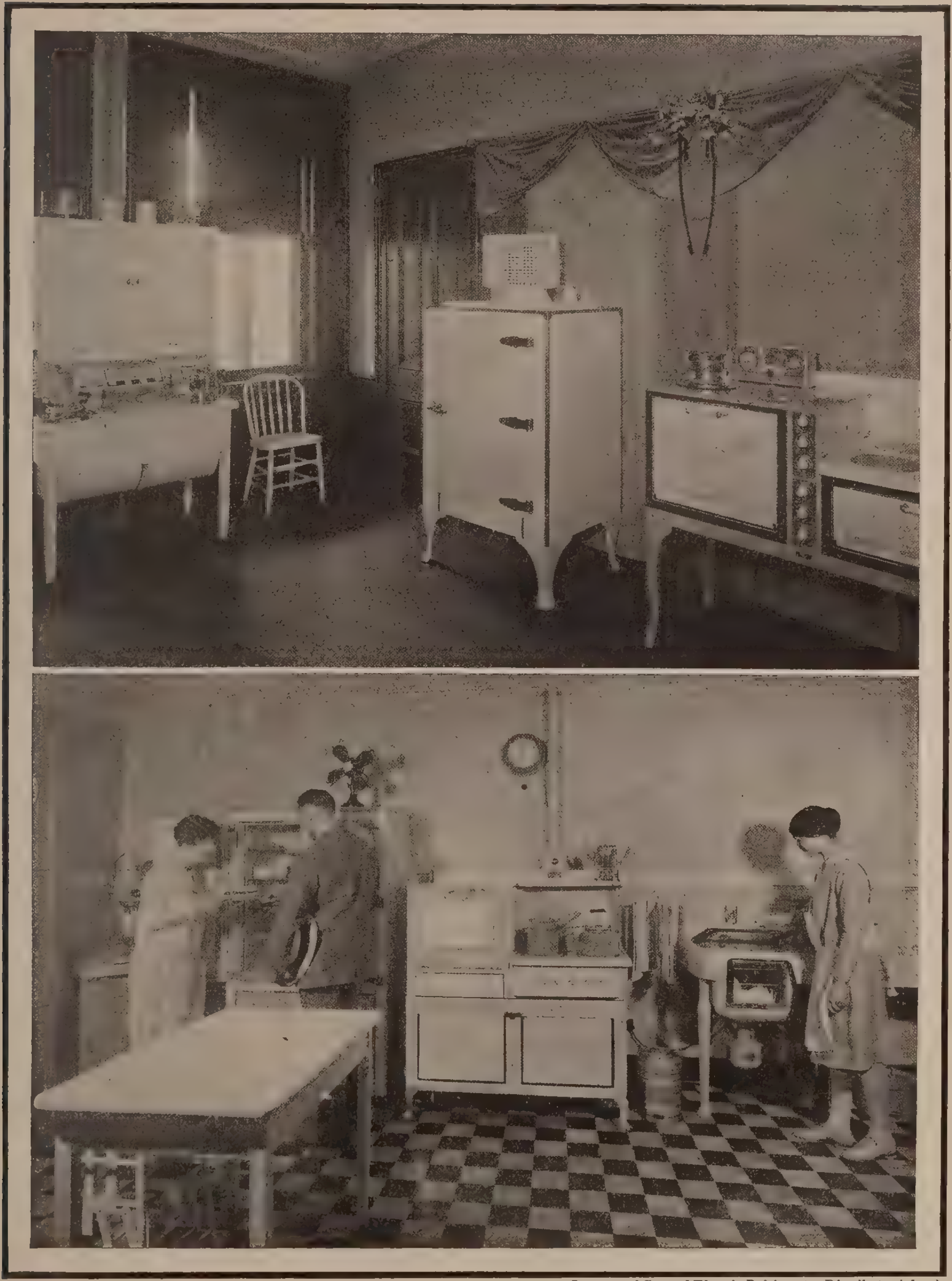
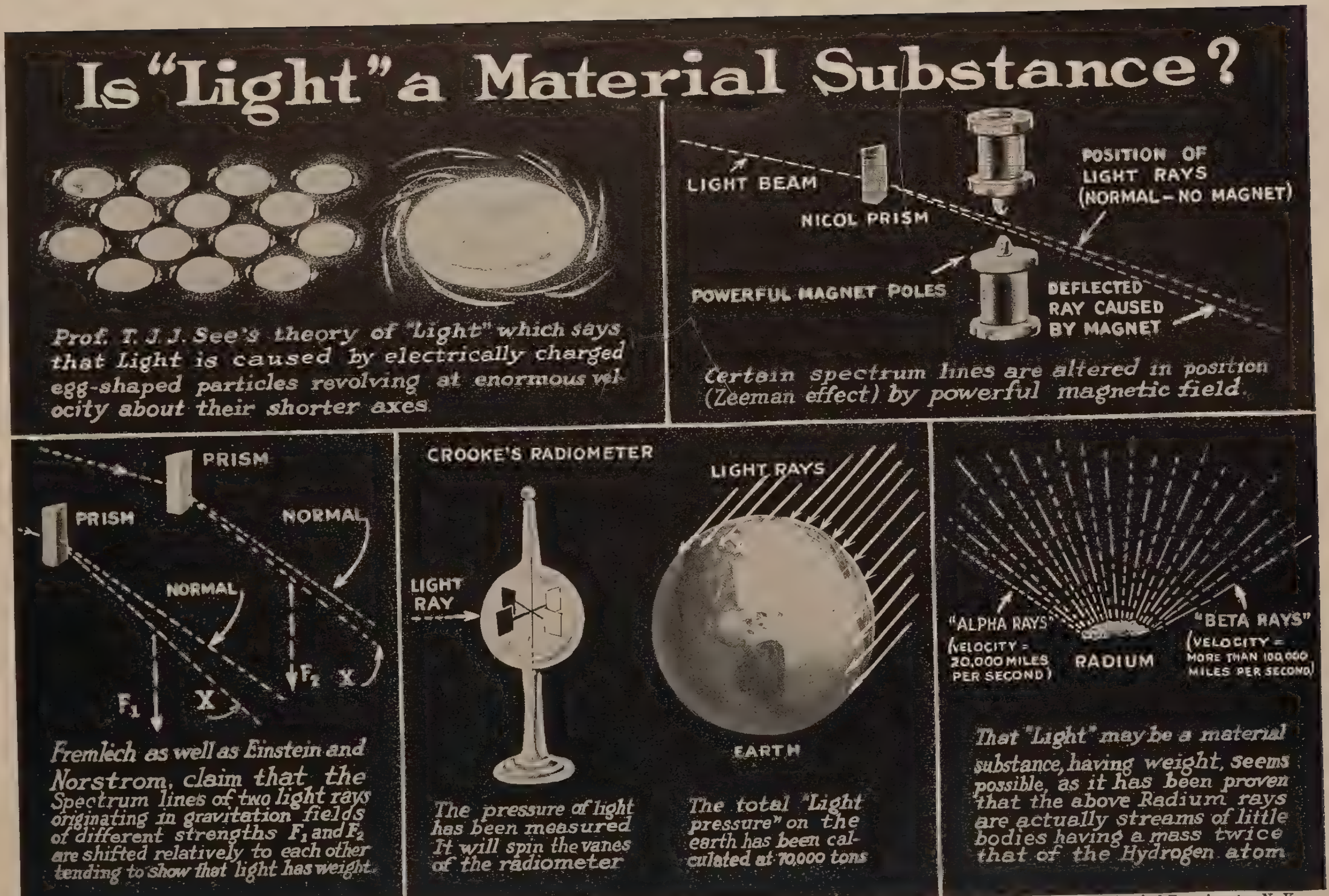
VILLA FERIA-ELECTRA, THE ELECTRIC HOUSE

Top, left: A visitor ringing at the gate. Right: The gate opens and a mysterious voice bids him enter. Bottom, left: Exterior of the house. Right: The owner's study.



Courtesy of General Electric Refrigerator Distributor (above);
Edison Electric Illuminating Co. (below).

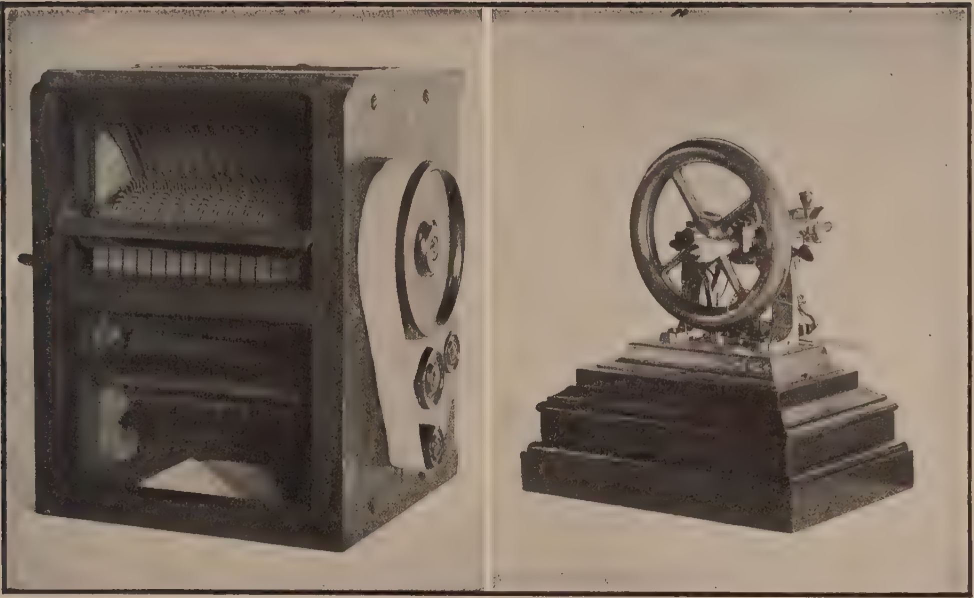
THE MODEL KITCHEN


Is "Light" a Material Substance?
Prof. T. J. J. See's theory of "Light" which says that Light is caused by electrically charged egg-shaped particles revolving at enormous velocity about their shorter axes
LIGHT BEAM
NICOL PRISM
POSITION OF LIGHT RAYS (NORMAL – NO MAGNET)
POWERFUL MAGNET POLES
DEFLECTED RAY CAUSED BY MAGNET
Certain spectrum lines are altered in position (Zeeman effect) by powerful magnetic field.
PRISM
PRISM
NORMAL
NORMAL
F₁
F₂
X
X
Fremlech as well as Einstein and Norstrom, claim that the Spectrum lines of two light rays originating in gravitation fields of different strengths F₁ and F₂ are shifted relatively to each other tending to show that light has weight.
CROOKE'S RADIOMETER
LIGHT RAY
The pressure of light has been measured It will spin the vanes of the radiometer
LIGHT RAYS
EARTH
The total "Light pressure" on the earth has been calculated at 70,000 tons
"ALPHA RAYS" (VELOCITY = 20,000 MILES PER SECOND)
RADIUM
"BETA RAYS" (VELOCITY = MORE THAN 100,000 MILES PER SECOND)
That "Light" may be a material substance, having weight, seems possible, as it has been proven that the above Radium rays are actually streams of little bodies having a mass twice that of the Hydrogen atom

Courtesy Electrical Experimenter, N. Y.

DOES LIGHT HAVE WEIGHT? IS IT CAUSED BY ELECTRICALLY CHARGED PARTICLES?

Scientists never cease to puzzle over the riddles and wonders of the universe. We cannot always follow their reasoning or understand their methods, but we can read and think about the results. Light comes to us in waves through an imaginary medium called *ether*, which is supposed to fill all space. Study this picture and see how these wise men work out a new theory of light as caused by electromagnetic movements in this ether and possibly having actual weight. (See also Vol. I, 93 ff.)



Copyright, Harris & Ewing

MODELS OF WHITNEY'S COTTON GIN AND HOWE'S SEWING MACHINE, IN THE NATIONAL MUSEUM, WASHINGTON

THE DEVELOPMENT OF SPECIAL MACHINERY

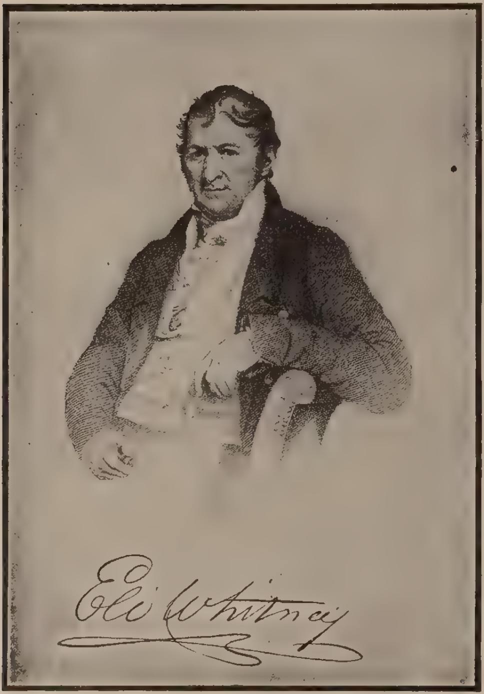
THE WEALTH–WINNING COTTON GIN

THE fabrics of olden times were woven mainly of wool or flax fiber. To-day cotton has largely taken the place of flax in many forms of manufacture the world over. The people of India have used cotton since the most remote times. The plant was introduced into America soon after its discovery by Columbus, but not until the beginning of the last century was it produced in any great quantity. Then the Southern planters found that they had just the climate for the growth of this plant and began to increase their crops of it. But the great trouble with the use of cotton for a fiber lay in the fact that it clung closely to the seeds and had to be laboriously separated by hand. This made its use slow and costly.

ELI WHITNEY'S EXPERIMENTS

Eli Whitney was a Massachusetts boy with a genius for mechanics. At the age of twelve he made a violin. A little later, in his father's absence, he took the family watch to pieces. After he had done it he was terror-stricken for fear he should not be able to put it together again. But he succeeded so well in doing this that his father never knew until told about it long years afterward. Through his industry and mechanical ability Whitney was able to earn his way through college, and later went to Georgia as a tutor. There he soon saw the difficulty with the cotton. Separating one pound of clean staple from the seed was a day's work for a woman. Whitney thought he could devise a machine which would make this work much easier, and he accordingly went about it. Another Yale graduate, Phineas Miller of Connecticut, lived near by and gave the young inventor substantial encouragement. Whitney had to make his own tools and draw his own wire for the invention, but he persevered, and by the end of the winter of 1793 the two were sure of the success of their machine.

Like most great inventions, the principle was



From "The Story of Textiles"

THE INVENTOR OF THE COTTON GIN

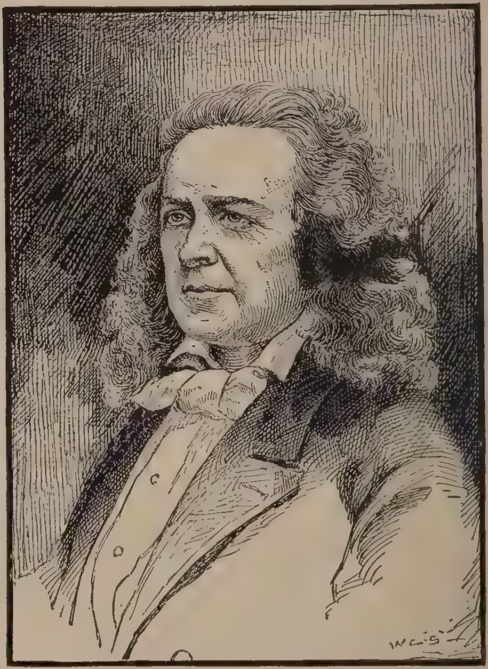
Though made famous by the cotton gin, Whitney gained nothing in a financial way from this epoch-making device. Fortune came to him later in his career from his inventions connected with the manufacture of firearms.

a simple one. The machine consists of two cylinders mounted in a strong wooden frame, one bearing a number of circular saws fitting into grooves in the other. The other is mounted with brushes which touch the tips of the saw teeth. The cotton is dropped into a hopper, is met by the teeth of the saws, torn from the seed, and brushed away into a convenient receptacle. The seeds remain behind, as they are too large to go through the bars through which the saws drag the cotton. Such was the first machine. Many improvements have since been made, but the year that the patent was taken out on that first machine the cotton crop of the South was but ten thousand bales. In fifty years, thanks almost entirely to Whitney's cotton gin, the crop had increased to many million bales. In 1860 the export amounted to four million bales.

This talented young mechanic thus added hundreds of millions to the wealth of his country, but he had to fight against chicanery and theft, and become involved in countless lawsuits and vexations, to retain even a trifling part of the value of his patents, so ungrateful is man. To his honor it should be said that he bore it all with patience, asserting his rights perseveringly and with unruffled good will.

THE ROMANCE OF THE SEWING MACHINE

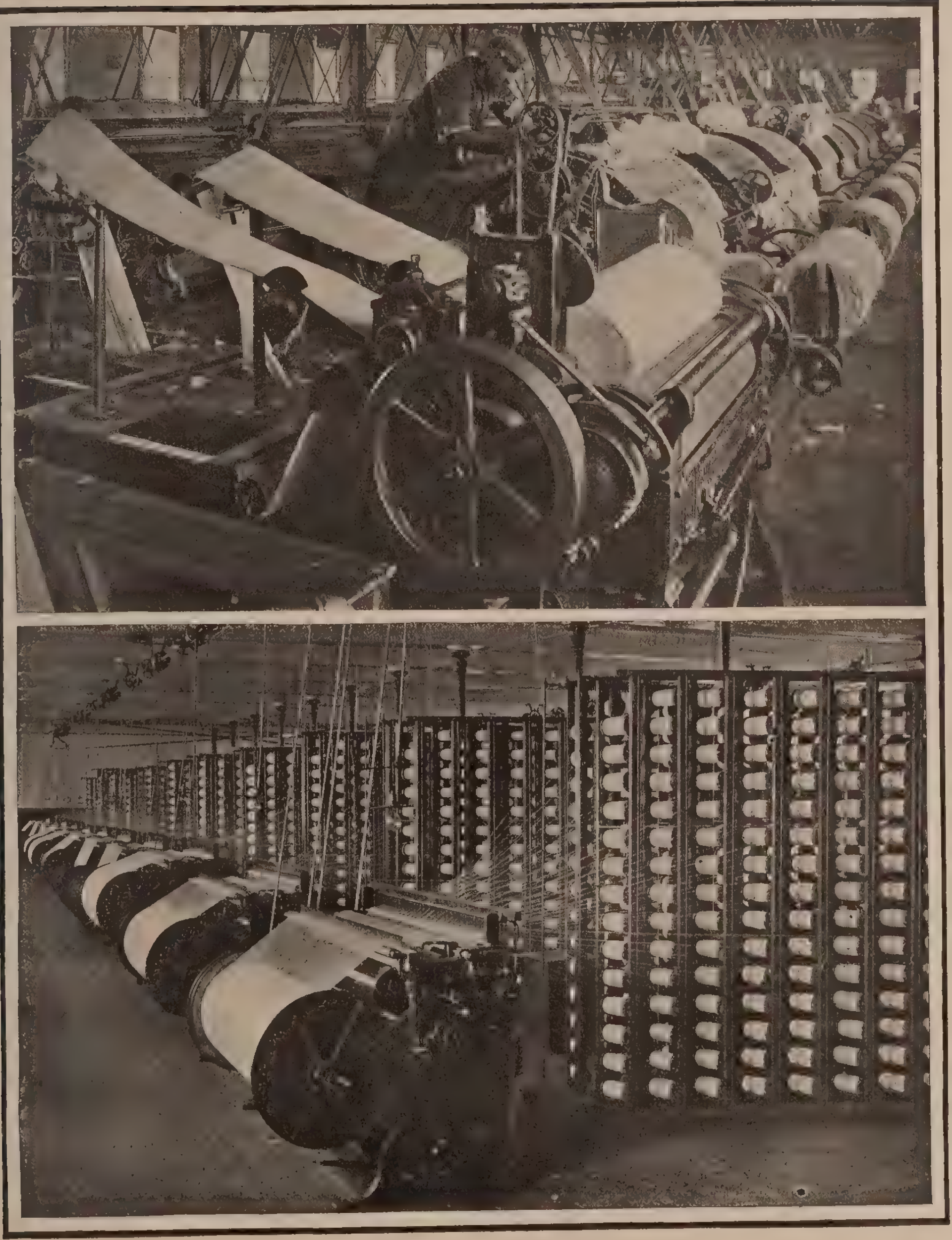
ALL labor-saving machines have been received with distrust by the very people to whom they were to bring the most help. Crompton, Arkwright, Hargreaves, Jacquard, inventors of textile machinery which has been a priceless boon to mankind, were all mobbed and persecuted. Hand weavers and spinners were furious that inventions should be made



From "Inventors." Copyright, Charles Scribner's Sons

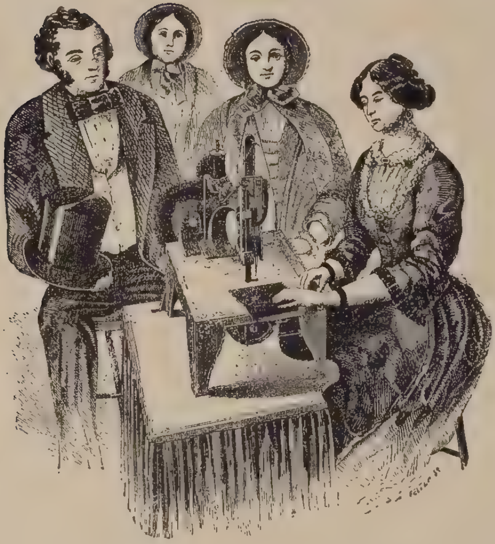
ELIAS HOWE

This humble machinist and persevering inventor lived to receive many honors, including the Legion of Honor cross.



TWO VIEWS IN A COTTON MILL

The cotton on first coming to the mill has been picked into fluff, or matted cotton, and cleaned of sand and dirt. In the upper picture we find it in the carding room. In the machines called "cards" the tangled fibers of cotton are made parallel. After leaving the carding room the cotton goes through other processes and is spun. In the lower picture it is in the spooling room where it is wound from the spools on to section beams, thence on to loom beams that go into the looms.



DEMONSTRATION OF FIRST SINGER SEWING MACHINE AT NO. 323 BROADWAY, NEW YORK

Copy of illustration published in August, 1853.

which would, as they thought, take away their opportunities to work. Thus Elias Howe, who took out the first United States patent and became the first United States sewing-machine inventor of record, although he had in mind the greatest labor-saving device ever introduced into the household, was abused and denounced as the enemy of man. But he persevered. Like Whitney of the cotton gin, he was a Massachusetts boy. He grew up a machinist, married, and had three children. His wages in the machine shop were small. He was frail, slightly lame, and poor. His wife sewed evenings to help keep the wolf from the door, and watching her toil bred in his heart the desire for a machine to lighten such labor. Taking counsel of no one, he worked upon this idea for a long time, setting up his shop in a garret of his father's house. He was so poor that often he lacked money to buy the iron and steel needed for his work on his models.

Howe made a machine which he knew would work, but he had not the money to complete it or to find a market for it. So perhaps we owe the modern sewing machine nearly as much to a coal and wood dealer of Cambridge, Mass., named Fisher, as to the inventor. Fisher took Howe and his family into his own home, provided a workshop, and lent Howe five hundred dollars for the construction of a first machine. In return Fisher was to be a half owner. It was in 1845 that Howe completed and patented his machine, which combined many novel devices. One of these, putting the eye of the needle at the same end as the point, had already been introduced in a sewing machine invented by two Englishmen. But Howe used it in a new combination, the needle being grooved and vibrating lengthwise, while a side-pointed shuttle whipped back and forth through the thread and locked the stitch. His first idea had the eye in the middle of the needle, which was double pointed and went back and forth through the cloth. Howe sewed with this first machine two woolen suits, one for himself and one for Fisher, the machine doing strong and accurate work.

But while all acknowledged that the machine was effective, no one would believe in its usefulness. He offered it to the tailors of Boston, and they told him it would ruin their trade. No one would invest a dollar in it. Fisher got discouraged and withdrew. Howe lost his position, went to England, where he worked for an umbrella maker for fifteen dollars a week, and tried to market his invention there. No one would buy it, but unscrupulous mechanics pirated his ideas and made machines of their own. He came back to Boston, arriving without money, just in time to see his dying wife. Then the ship in which he had sent home his household goods went to the bottom.

But this was his darkest hour. The English pirates had succeeded in bringing his machine to the notice of the newspapers, which called it a wonder. His patent was strong and he found money to defend it, and in 1850 he began to manufacture the machines in a small way in New York.

Meanwhile other inventors were at work. In 1851 A. B. Wilson, a Michigan cabinet maker, also constructed a sewing machine, although he had never seen one. This had some ingenious improvements upon Howe's machine. Wilson was the most original and had perhaps the finest inventive genius of any of the sewing-machine inventors of his day.

At about the same time Isaac M. Singer patented the first "rigid-arm" sewing machine and made important improvements in the shuttle. Mr. Singer was born in Oswego, N. Y., October 27, 1811, and was early apprenticed to the trade of machinist. He spent years of study on the original sewing machine, which he was sure could be improved. Finally he obtained a patent on a single-thread, chain-stitch machine and built a factory. He made a fortune, as he deserved to, and died in Torquay, England, in 1875. The Singer machine has formed the basis for all sewing machines manufactured since his revolutionary improvement was patented.

It was not till 1855 that Howe found the tide of fortune turning in his favor. Even then the garment workers denounced him and there were riots at the places where the machine was used. Besides this the other inventors of sewing machines had started manufacturing them. Lawsuits over patents ensued, and there was much bitterness of feeling between the rival companies. But these differences were all finally settled. Howe's royalties increased in six years from $300 to $200,000 a year. The poor mechanic had made his fortune and done his share in conferring an inestimable boon on the households of the world.

The companies founded by Isaac Singer and by Wheeler and Wilson greatly prospered, and are to-day among the world's chief producers of sewing machines. In fact, taking into account the numerous American companies now manufacturing sewing machines, the United States leads the world in this industry, both in quantity and quality of output.

MACHINES FOR MAKING MACHINES

IT will have already occurred to our readers that the making of all these machines must of itself employ many men and much capital. And this is indeed true. Skilled machine-shop mechanics are among the most highly paid workmen in the world. The machines that are used in making machines are among the most perfect. For just as a shift of the fraction of an inch in the pointing of a gun will send the bullet wide of its mark, so trifling inaccuracies in these machines for making machines would produce most disastrous results. In fine machine work it is common to demand accuracy to one thousandth of an inch, or even less.

MEASURING THE TEN THOUSANDTH OF AN INCH

There are many forms of gauges, or micrometers, for measuring to minute fractions of an inch. One of the most usual types is that illustrated in our drawing, *D*, on page 91. It will measure to the ten thousandth of an inch. The measurement is made by dividing the pitch of the thread of the adjusting screw by the fraction of turn given in making the measurement. If one complete turn of the barrel moves the gauge one thousandth of an inch, one tenth of a turn will move it one ten thousandth of an inch. Of course the machines are set by similar devices. But the workman does not depend upon this setting of a machine. He continually tests his work with his micrometer caliper.

THE LATHE

This is one of the most important machines in a machine shop. A lathe is a machine for turning the work against a fixed tool. A steel-working lathe moves very slowly. The tool is held in an adjustable rest, and the work is revolved by a headstock on which a variety of chucks for holding the piece may be used according to the need of the work, or the piece may be held between two centers, one in the headstock and one in the tailstock. Much time is spent in making the adjustments, after which the machine takes care of itself. As most machinery is made up of revolving, that is cylindrical, parts, the use of the lathe is very extensive. Lathes are made to turn the smallest axles for fine watches and also to turn huge cannon of eighty or one hundred tons of the hardest steel. There are few more fascinating sights, to one interested in mechanics, than a lathe at work peeling long ribbons of steel from a great shaft or tiny, almost invisible, hairs from some exquisite little pin.

THE MILLING MACHINE

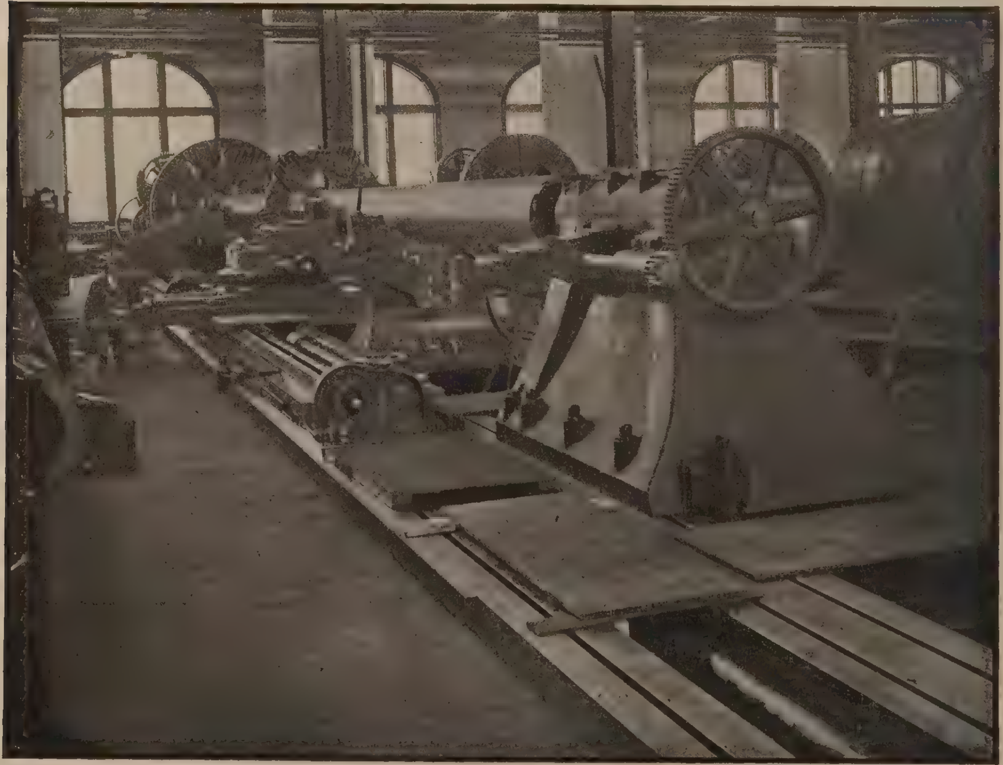
The milling machine is the machinist's man of all work. The illustration on page 91 shows what is called a "Universal Milling Machine." It has a table for the work, arranged with "feeds," by which all classes of plane, circular, helical, index, and other milling may be done. On such a machine a piece of steel may be rounded, a thread cut, and a slit made in the head, for a screw, with one setting of the machine. It seems to have no limitations of capacity. A milling machine differs from a lathe in that the tool is a revolving cutter against which the work is pressed, while in a lathe the tool is a fixed edge or point against which the work turns.

THE PLANER

This is a machine for producing plane surfaces on metals, and is also shown on page 91. The work is held on a table which runs back and forth under the tool, which is stationary. This cutting tool shaves off successively, side by side, thin strips of metal, until a perfectly flat surface is produced. The machines are found in varying sizes. On the larger ones the tables are from seven to eight feet in width and twenty feet long. While the uses of the planer are not as varied as the milling machine or the lathe, it has many adjustments that in the hands of an ingenious and skillful workman produce an amazing variety of work.

Of course there are many varieties of this as of other instruments. Our illustration shows only the most usual type.

Drills, forges, cutters, and other machines are used, but the three great machines above described, with micrometer calipers for purposes of measurement, are the foundation of machine-shop work. Many automatic machine tools are also used which need almost no attention.



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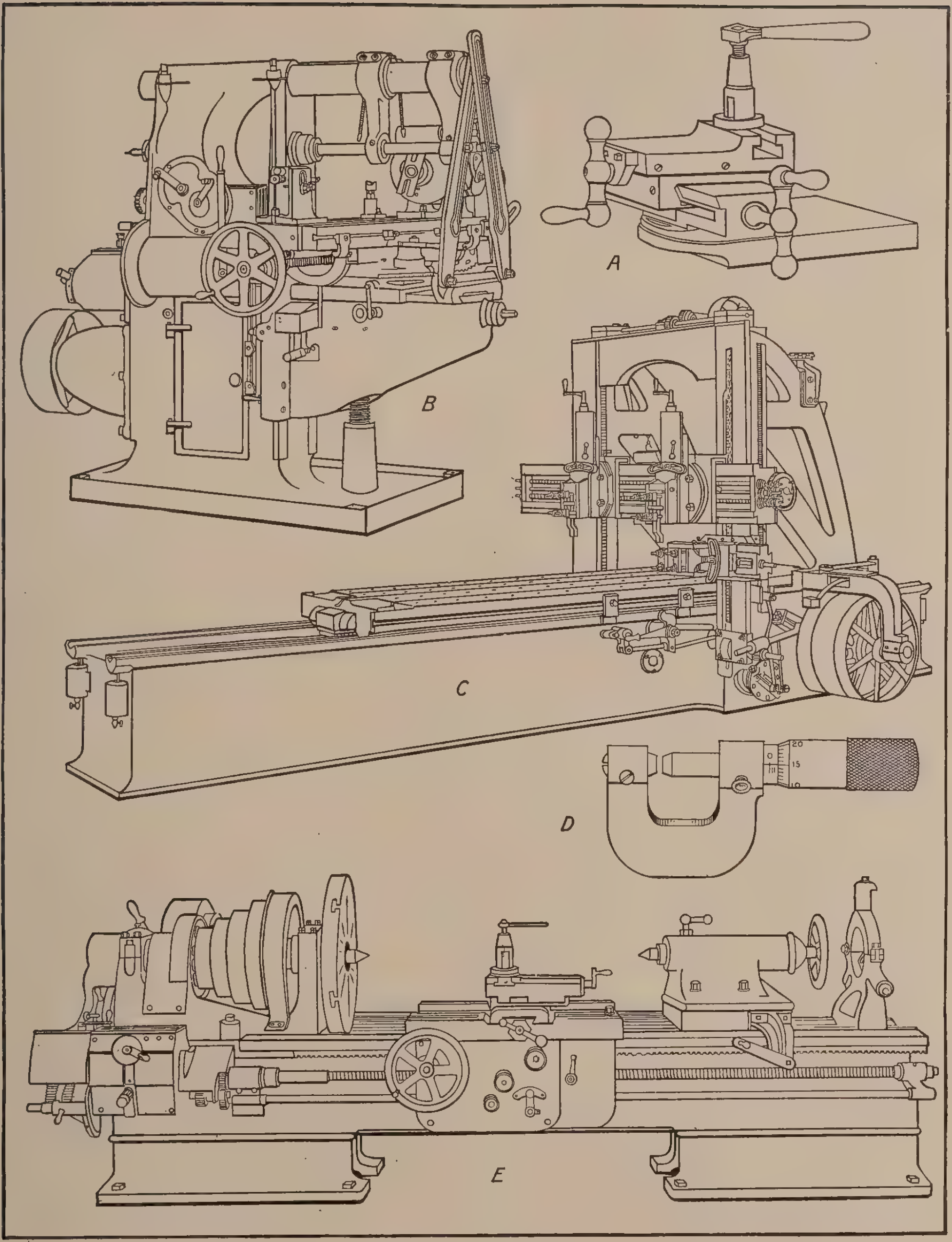
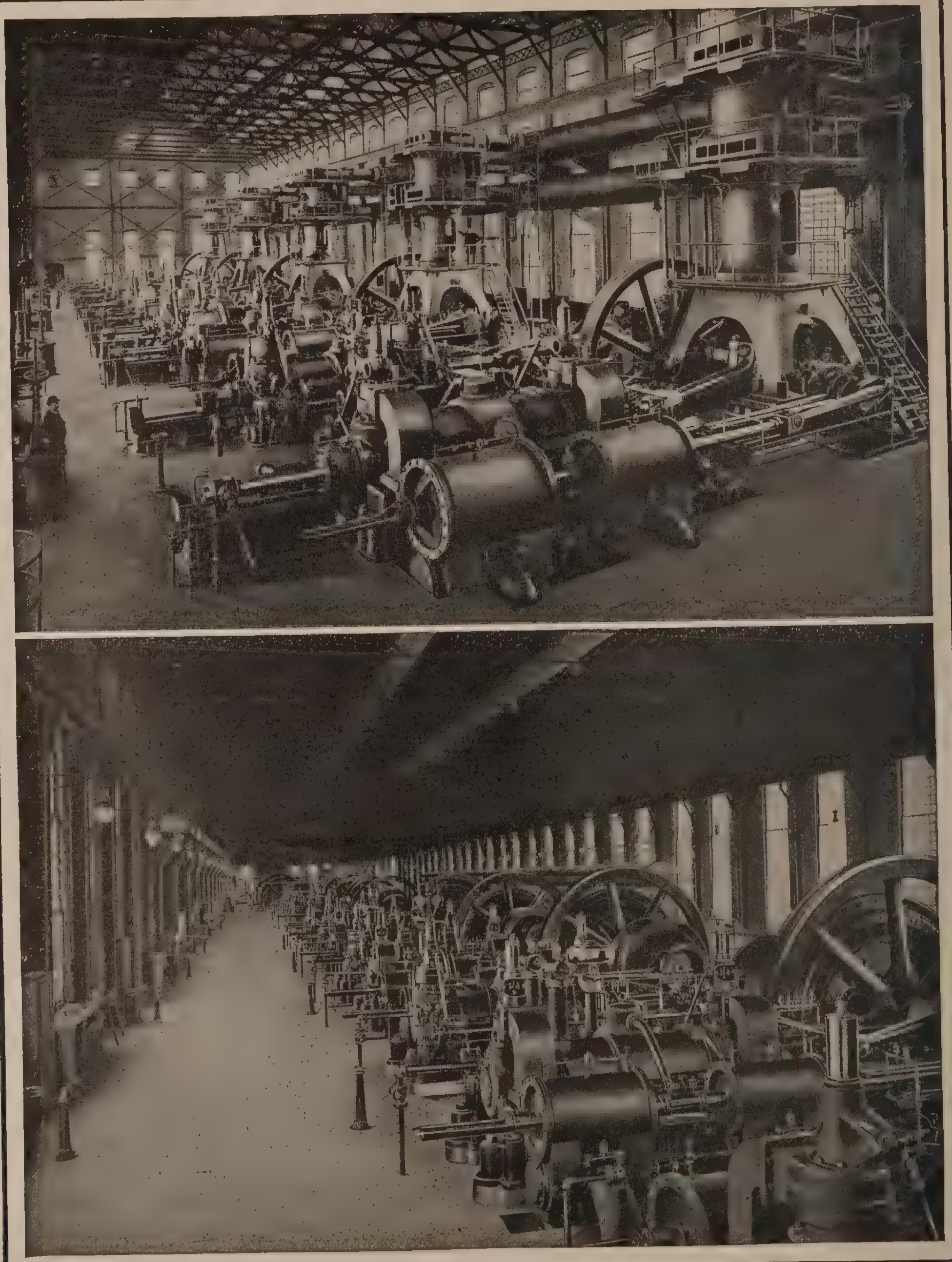
LARGE LATHE FOR TURNING GREAT GUNS



MACHINE-SHOP MACHINERY

A. Tool rest or holder used on lathe. *B.* A milling machine. *C.* A planer. *D.* A micrometer caliper. *E.* An engine lathe



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SOME GIGANTIC ENGINES

Top: Five of sixteen 2000-horse-power Körting gas engines built by the De la Vergne Company of New York City for blowing the blast furnaces of the Lackawanna Steel Co. Bottom: The same engines attached to the generators.

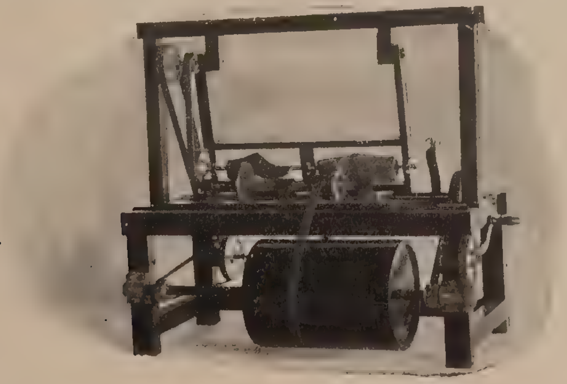
THE MARVELOUS DEVELOPMENT OF SHOE MACHINERY

THE first machine to be widely accepted by the shoe manufacturers was the rolling machine. This was used for rolling the sole leather under pressure, and it is said that a man could perform in a minute with this machine the same office which would have exacted half an hour of his time with the old lapstone. Elias Howe's sewing machine, of which we have already given an account, was soon followed by a machine for sewing with waxed thread. But the real revolution in the manufacture of shoes came in 1858, with the invention of the McKay sewing machine. The inventor of this machine was Lyman P. Blake. The McKay machine did not at this time sew the toe or heel, but the sewing started at the shank and was carried forward to a point near the toe, first on one side and then on the other. The financial difficulties of promoting the use of this machine led to the invention of the royalty system. Stamps were sold to be affixed to each pair of shoes made by the machine. The plan was wonderfully successful. In 1862 an inventor named Matthias, working for Mr. McKay, devised a machine for sewing clear around the toe. This was first used by Gilmore Brothers in filling a contract for army shoes. The entire sole was sewed round and round, as if it were quilted, the sewing beginning at the edge and ending in the middle. It was a very crude machine, but the shoe was a success, and the McKay machine was established as an economic necessity. It has since been greatly improved.

The inventor of the Goodyear welt machine was a New York mechanic named Auguste Destoye. His machine was not a success, although he furnished the fundamental idea. Mr. Charles Goodyear became convinced of its practicability and engaged other mechanics to work on it, at last producing a machine for sewing, first, turn shoes and finally welt shoes.

The invention of a machine for making shoe tacks seems like a small thing, but it has made many fortunes. Large shoe manufacturers buy tacks by the ton. The industry is still centered near Bridgewater, Mass., where it originated. Mr. Goodyear added to the machines for doing parts of the work on welt shoes. He devised machines for stitching the insole to the outsole, for channeling the insole and outsole, for automatically leveling, etc. His machines constituted a system, known as the welt system, and it is this system that has been the subject of constant improvement.

Mr. Matzeliger, a Lynn inventor, devised what is called the "hand method lasting machine." By this invention almost the last trace of hand work disappeared from the manufacture of all but shoes for special trade. The American machine-made shoe is one of the greatest triumphs of the Age of Machinery.



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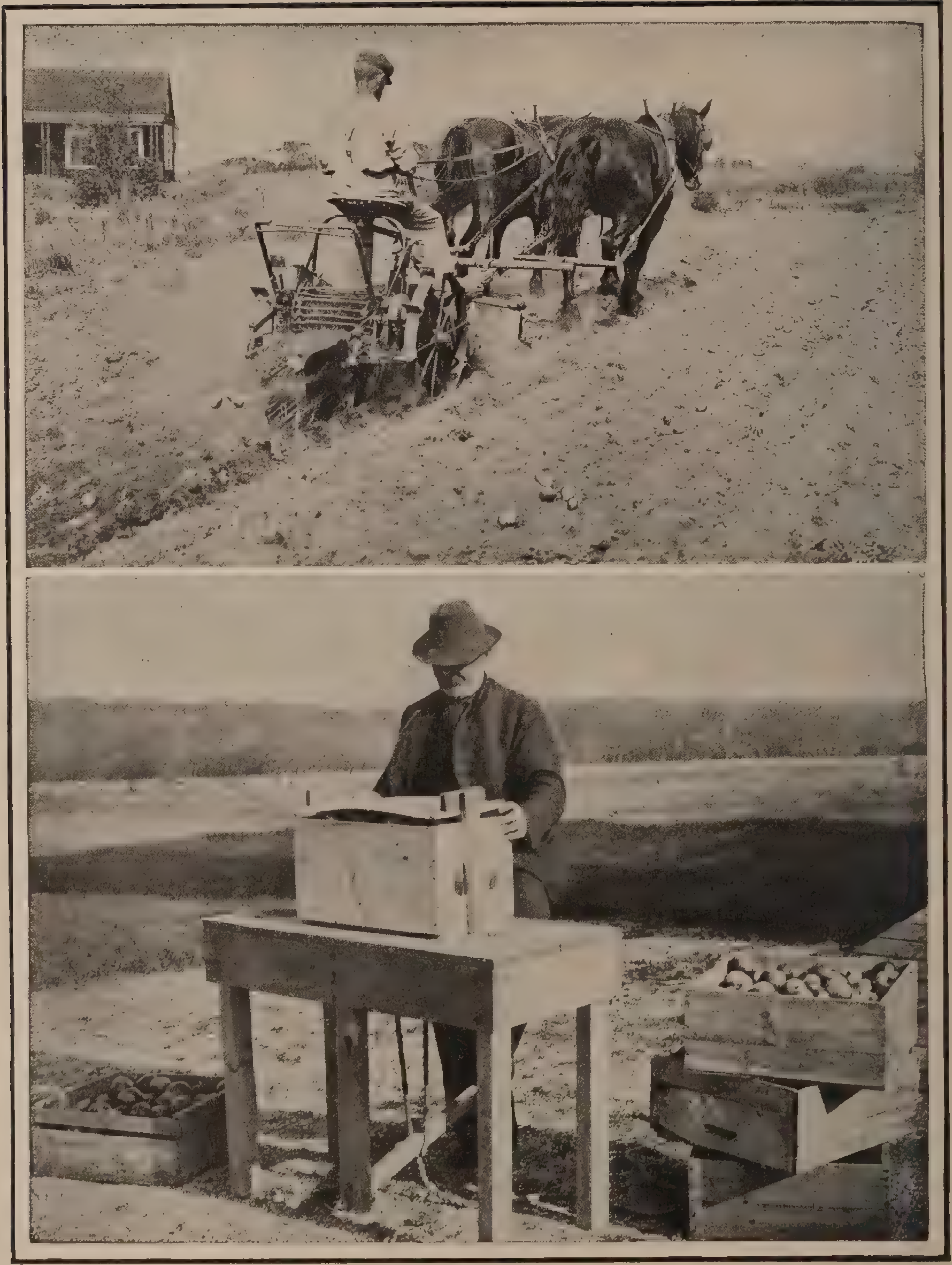
MODEL OF A BLANCHARD LATHE TURNING OUT SHOE LASTS



MACHINES FOR THE FARM

Top: The new way of digging potatoes. Bottom: A device for packing apples without jamming.

A MODERN RIDING PLOW

The sod is cut by the wheel which runs ahead of the plowshare.

AGRICULTURAL IMPLEMENTS

THUS far we have considered only machinery for producing power, making clothing, and transportation. What has machinery done toward feeding mankind? Not as much, in some ways, and yet more than we would believe without careful study.

As we realize that the greatest nations have been agricultural, we may well wonder how the ancient farmers accomplished so much with their primitive tools — the crude plows, sickles, and scythes. Agriculture was the hardest kind of manual labor. The strange thing is that conditions remained practically unchanged for thousands of years; and the farmers of Europe, and of our own country as well, down to the middle of the last century, were still using the crude tools of the ancient Egyptians and Israelites. Invention at last turned its attention to the farm, and by 1850 a new era had begun, with the introduction of agricultural machinery. To-day machines in great variety and of wonderful inventive genius are in use in all the operations involved in soil preparation, planting, harvesting, and marketing the products.

TILLAGE MACHINERY — PLOWS

The chief implements for preparing the soil are plows, harrows, and cultivators of various kinds. The plow turns the furrow completely over and exposes the soil to the air. The first plow was simply a form of hoe made from a crooked stick. Then larger plows were made and horses and oxen were set to draw them. Nowadays plows, harrows, and cultivators have all been adapted to use of power. Early plows were made of wood plated with iron, and, strangely enough, no great improvements were made in them through the centuries. Daniel Webster is said to have designed a large and clumsy plow for his Marshfield farm. It turned a furrow eighteen inches wide and required several men and a yoke of oxen to operate it.

Steel plows were first introduced when farming in America moved farther west and the settlers were obliged to wrestle with the tough sods of the prairie states, with which the old iron-plated plows were unable to cope.

Walking plows are made to cut furrows from eight to eighteen inches. A plow cutting a fourteen-inch furrow is considered a two-horse, and one cutting a sixteen or an eighteen inch furrow a three-horse plow. The name "sulky plow" is used for all wheel plows, but applies more particularly to single plows; while the name "gang plow" is given to double or larger plows. Gasoline tractors are now used instead of horses on almost all large farms.

CUTTING ENSILAGE CORN AND FILLING A SILO BY MACHINERY

Ensilage is green fodder preserved for winter feeding by compressing in a silo and keeping from the air.

HARROWS, CULTIVATORS, AND ROLLERS

After plowing the ground it is necessary to pulverize the soil very finely before putting in the seed. Harrows and cultivators are the implements used for this purpose. The most common type of harrow is the smoothing harrow, made usually with straight, fixed teeth of wood or iron. The spring-tooth harrow has curved teeth, which spring back and are released when caught on any obstacle. It is very useful for stony ground and is also an excellent pulverizer. But the most useful of all harrows is the disk harrow. On account of its rolling action it can be used for many different conditions, and by some practical farmers it is made to take the place of the plow itself.

After the soil has been smoothed by the harrow, the cultivator does its part in making the furrows for the planting of the seed. And after the seed has been planted it performs the same service as a hand hoe in keeping the soil in good condition.

Implements called "rollers" are also used to break clods and to make the seed bed smooth after sowing.

PLANTING THE SEED

The old way of sowing seed was by hand. Now we have various kinds of drills, broadcast sowers, and seed barrows. Drills deposit the seed in rows, below the surface, while broadcast machines and seed barrows scatter the seed on the surface or on furrows. Drills include water drills, dry drills, corn drills, turnip drills, clover drills, etc. The drill is displacing to a large extent the broadcast seeder, because the farmer desires to place all the seed in the ground and at the proper depth.

SAWING WOOD AND BALING HAY WITH POWER FROM GASOLINE ENGINES

An important machine called a "corn planter" is strictly an American invention, for corn or maize is peculiarly an American crop. Until the development of this machine, corn used to be planted and covered with the hoe. In some states, particularly Kansas and Nebraska, the device has proved a valuable aid to the farmer. For small crops, hand planting will probably give the best results, but on large tracts of land, in regions where wages are high and time is an important factor, advantages attach to the use of the machine.

HARVESTING AND THRESHING

It is in the field of harvesting and threshing machinery that the greatest advance has been made over the early farming tools. There are in this class harvesters, self-binders, reaping machines, headers, combined harvesters and threshers, mowing machines, loaders, stackers, swath turners, horserakes, hay tedders, etc.

The machine for reaping the grain, however, has achieved the greatest wonders in modern farming. Think of the immeasurable difference between the sickle and cradle and the modern reaper! The sickle, as we know, was used from time immemorial as a harvesting tool, the scythe being a slight improvement upon the sickle. The cradle was an American device long in use. In 1834 came the reaper, one of the most important inventions ever given to the world, the machine that, for the first time in history, *made bread cheap.*

Courtesy of International Harvester Co.

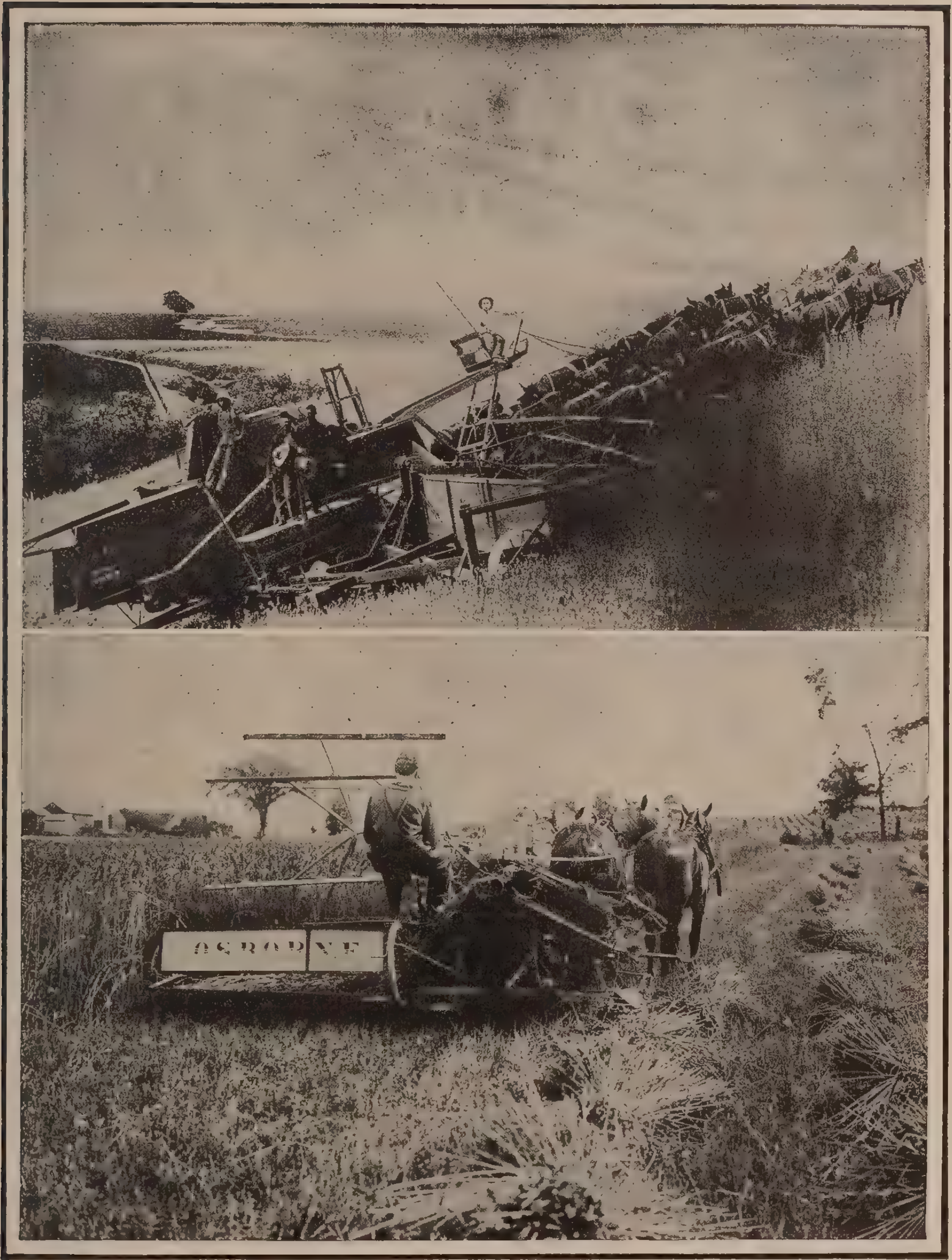
THE McCORMICK REAPING MACHINE OF 1834

Flailing was the common method of threshing grain as late as 1850, but treading with animals was a method also much used. The flail was simply a short club, usually attached to a handle by a piece of leather. After the grain was beaten from the head or ear with the flail, the straw was carefully raked away and the chaff separated from the grain by fanning or by letting the wind blow it out.

The modern threshing machine is a highly ingenious and complicated invention which shells the grain from the head, separates the straw from the grain and chaff, extricates the grain from the chaff and dirt, and finally delivers the grain to one place and the straw to another.

THE MACHINE THAT MADE BREAD CHEAP

OVER thousands of square miles of our Western prairies the wheat grows, waving in the wind like a golden sea. It is a world of wheat in which often the eye sees no other horizon, an ocean of verdure which is destined to feed the world with its golden grain. Without the wheat of the Western prairies, famine would stalk the land the world over. And without the reaper the golden grains would rot in the fields, for nowhere could be found sufficient labor to harvest it by hand in the primitive way which was common little more than



Courtesy of International Harvester Co.

TOP: A COMBINED HARVESTER AND THRESHER, WHICH CUTS A SWATH FOURTEEN FEET WIDE. BOTTOM: A MACHINE FOR BINDING WHEAT IN SHEAVES a half-century ago, a way that was the only one from earliest ages until a Virginia lad, son of a farmer, made a mechanical reaper.

THE STORY OF ITS INVENTION

Cyrus Hall McCormick was brought up on a farm. As a boy of fifteen he was accustomed to go into the wheat fields and "cradle" the grain with the hand reaper, and it is worthy of note that at that age he constructed a superior hand implement by means of which he was able to harvest as much wheat as a full-grown man. But his father was more than a farmer. He had a large workshop on the place, a saw and grist mill, and smelting furnaces. In all these young McCormick learned practical mechanics and made several minor inventions. One of these was a plow which threw furrows to the right or left as desired. But as he grew up he became absorbed in a desire to invent a mechanical reaper. His father had tried this and had failed, losing much money by his experiments, and he discouraged the boy. But young McCormick persisted. He found that his father's machine would cut grain that stood perfectly straight in the field, but he knew that a practical machine must cut grain whether it stood straight or was beaten down — lodged — by the rain and wind. The grain must be cut, stalks and all, no matter how it might happen to stand.

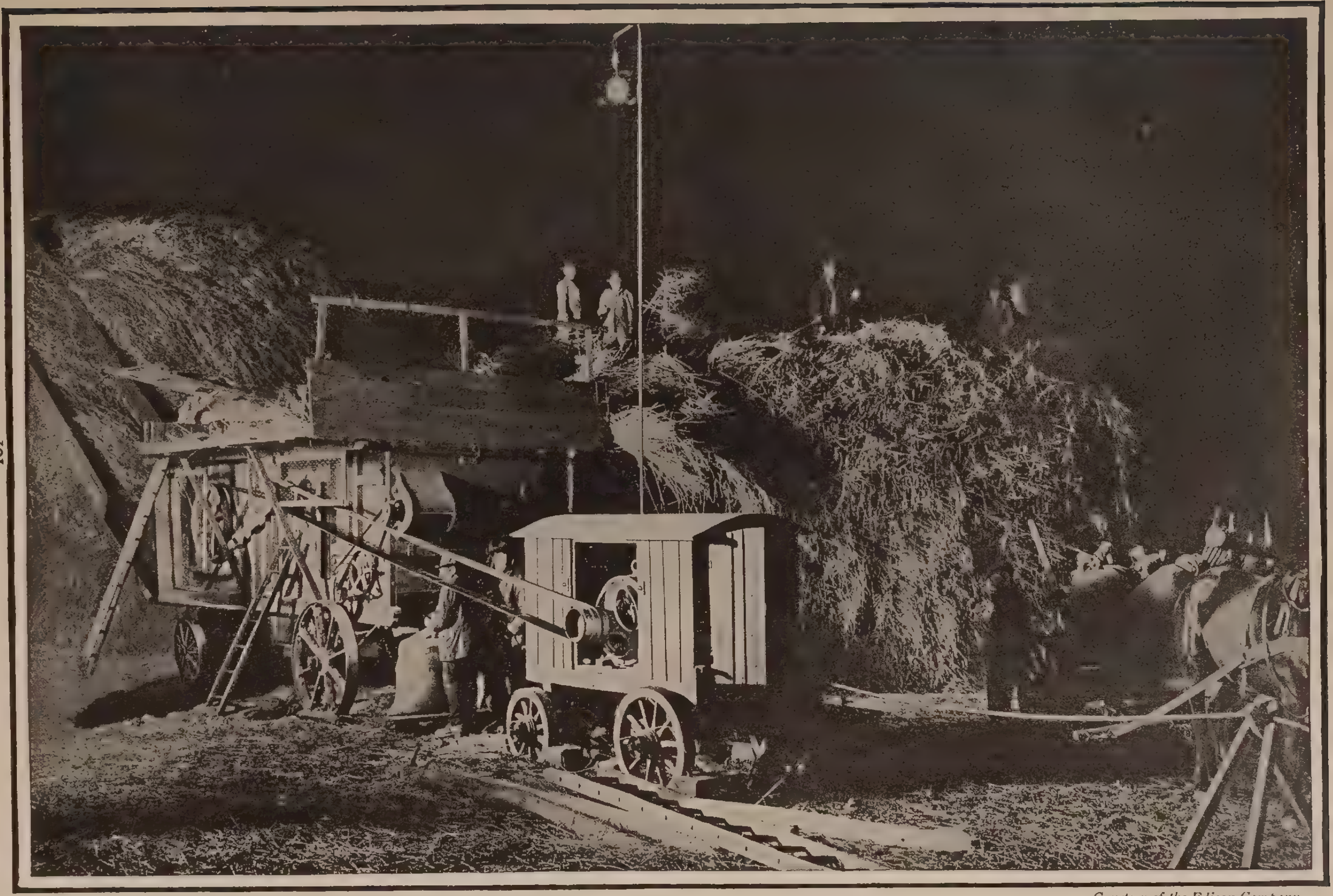
In his father's shop he worked patiently, making every part of the machine himself, whether of wood or iron, and he finally produced there in 1831 the first reaper that ever really cut an average field of wheat satisfactorily. The four great essentials were those of the machine of to-day: a vibrating cutting blade, a reel to bring the grain within reach of the blade, a platform to receive the falling stalks, and a divider to separate the grain to be cut from that to be left standing. This machine was drawn by horses and its work astonished the farmers who saw it in operation. With it one man could do the work of many and the problem of handling the great wheat fields of the future was solved.

From the little blacksmith shop on the Virginia farm the making of McCormick reapers has grown to a vast industry, more than 2000 men being employed in a single factory using more than 20,000 tons of bar steel, 2800 tons of sheet steel, and 26,000 tons of iron castings in a year's work. More than 2,000,000 reapers based upon the McCormick patent are at work in wheat fields of the world each year, not only on the great prairies from Texas to the far Canadian Northwest, but watched with awe by the natives on the steppes of Russia, and in India and Egypt. For the use of the reaper vast wheat fields are planted in Argentina and Australia. The reaper is one of the labor-saving wonders of the age. It has kept millions of men from drudgery and millions more from famine. It is estimated that the use of the reaper increases the world's wealth by hundreds of millions of dollars every year.

REAPING EVERY DAY OF THE YEAR

Not a day in the year passes but reapers are busy cradling the world's supply of grain. Harvesting begins on the Rio Grande in Texas early in the summer. In any given locality it lasts but about ten days, and in thousands of miles of wheat fields thousands of reapers are busy from dawn until dark. Great stacks of garnered grain pile up behind them as they go, and still they move steadily over the fields, each doing with ease the work of six men, yet making more work in many different ways for sixty others. Little by little this harvesting zone moves north, busy workers moving with it till it ends in the great plains of northern Canada with the coming of the winter.

But what is winter north of the equator is summer south of it, and when the reapers cease here they begin there. When the harvest ends in America, and on the small, well-tilled fields of Europe, the steppes of Russia, the far-distant plains of India and China, it is beginning in southern Brazil and northern Argentina, to end only when snow flies and the ice sets firm about Cape Horn. So it is in South Africa and Australia. Thus bread is cheap the world round— the staff of life on which all may lean, and the machines that made it so work ceaselessly for the benefit of man. The whir of their wheels follows the sun on his round, swaying now north, now south, with the varying equinox, but never ceasing in its music of beneficial labor.



Courtesy of the Edison Company

OPERATING A THRESHER AT NIGHT WITH A PORTABLE MOTOR OUTFIT

A COMPOSITION ROOM

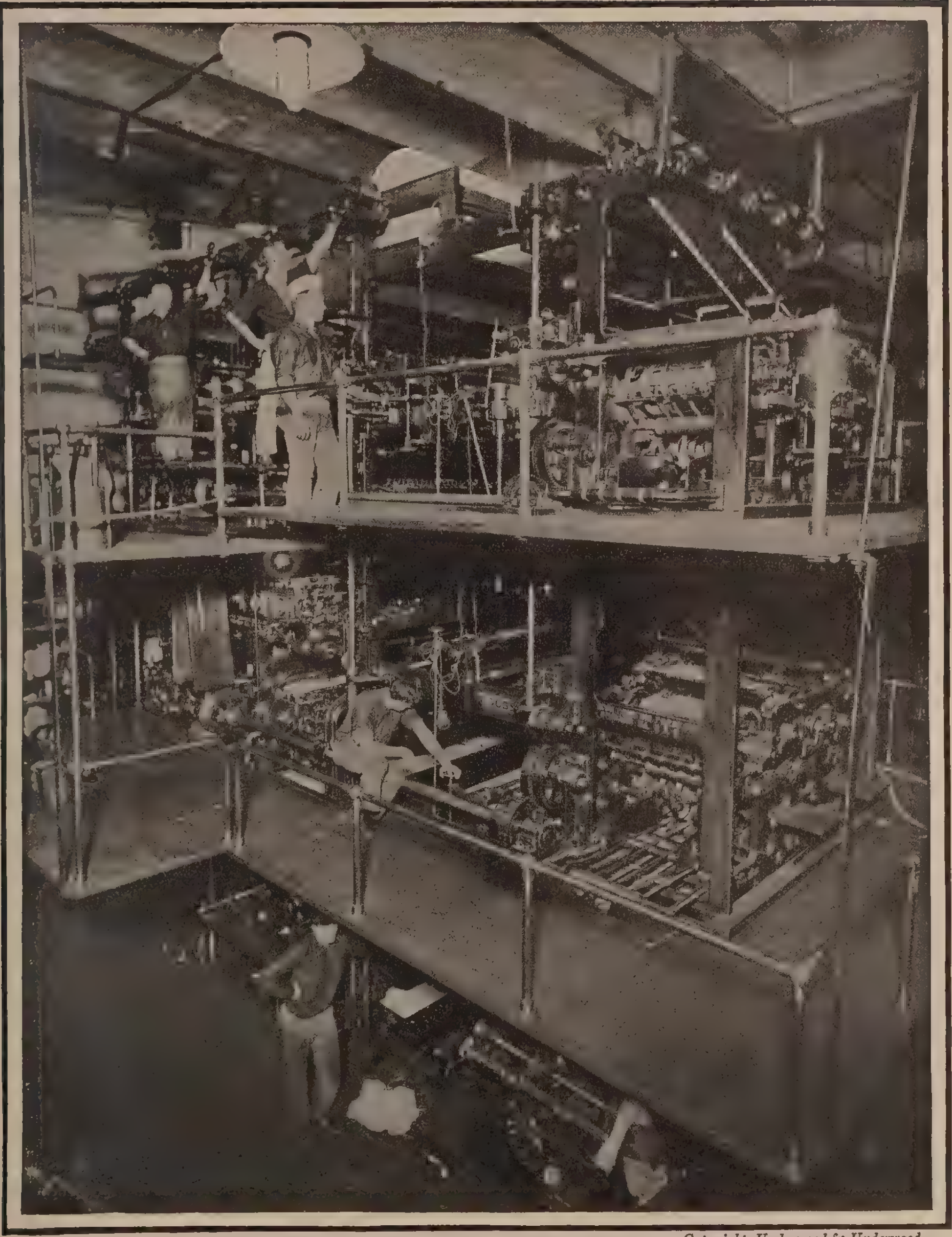
In the rear, beside the windows, are the cases from which the compositors set the type. In the foreground are the stones on which pages of type are placed to be locked up in iron chases.

PROGRESS IN PRINTING

NOT until the nineteenth century was much real progress made in the mechanical part of printing. In common with all machinery, after the invention of steam, the printing press was improved and enlarged and adapted to the use of power. These improvements took the form of the use of a cylinder, instead of a flat plate, to press the paper against the type; and finally of two cylinders rolling in contact, one carrying the type and the other the paper. The United States rapidly took the lead in these inventions and has maintained it. R. M. Hoe of New York made remarkable advances, and the Hoe presses are still among the most famous in the world. Babcock, Gordon, Cottrell, and Miehle are other great American inventors and manufacturers of improved printing presses.

The progress that has been made is in speed and economy. On an old hand press two men could print in an hour one side of one hundred sheets up to eighteen by thirty inches in size. These two men received about seventy-five cents a day for their work. A modern power press will produce seventy-two thousand impressions on both sides of a twelve-page newspaper in an hour, delivering them folded, pasted, and ready to sell. Such a press requires the attention of from five to ten men, who can accomplish far more even at a higher wage.

Not only has the slow little hand press been superseded by the great power press, but typesetting by hand has largely given way to the



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THE HUGE PRESS OF A GREAT CITY NEWSPAPER

A great roll of paper is fed into one end of such a press as this and complete newspapers, printed and folded, are promptly delivered at the other end.

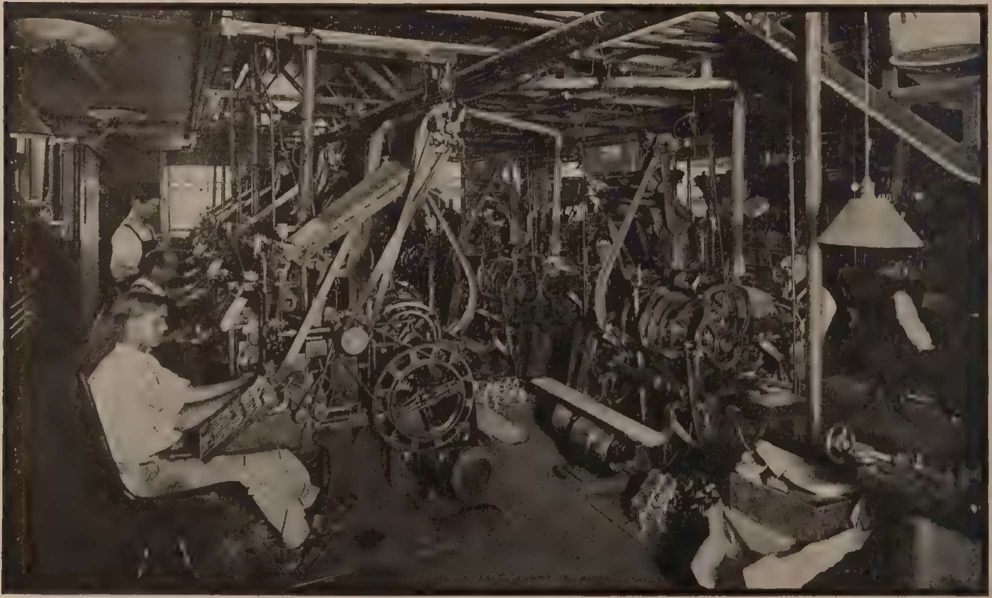
typesetting machines. These machines do not literally set type. They cast new type from brass molds, while the typesetter merely presses the keys of a board similar to that of a typewriting machine. There are two kinds of typesetting machines — the linotype and the monotype. The linotype casts a line of type in one solid piece of metal (hence the name "line-o'-type"), while the monotype (*mono*, "one," "type") casts each letter separately.

The linotype, invented by an American, Otto Mergenthaler, was long regarded as impracticable, but when perfected its speed and economy, especially for newspaper work, soon made it a necessity in all large offices. It is a machine that gives one an almost uncanny feeling as one watches its operation, so human is it in its movements. The operation of writing and casting is performed by the one machine. The operator sits at the keyboard, and as he presses a key the process begins which is to put the letter or character which the key represents into place as part of a line. If a single error is made, the whole line must be remade. This is the slow feature of the linotype. The illustrations show better than description the workings of this marvelous invention, justly described as one of the most ingenious and complicated ever produced by the brain of man.

The monotype, which came later, differs from the linotype in many respects. The operator writes upon a specially prepared paper or ribbon, the perforations in which resemble somewhat a music record. The casting is done by a separate machine, and the ribbons can be filed away for future use. As the letters are formed separately, corrections can be made as in ordinary hand-set type. The type metal is a little firmer also, and broken or imperfect letters are not so frequent.

The compositor still has his place, however, in the modern printing office. There are always jobs to be done by hand work, besides the display work, the making-up, and the designing of pages, which no machinery can do.

A modern printing establishment is one of the wonderful products of our inventive age. The story of the progress of an individual book as it passes through the hands of the printer and the binder is told more in detail in Volume X.



LINOTYPE MACHINES

Note the little piles of "type metal" on the floor, ready to be put into the melting pot on each machine and immediately cast into type.

Courtesy of General Electric Refrigerator Distributor

SCIENTIFIC REFRIGERATION

THE great cry of our day is conservation. We are discovering that we have wasted our resources and are threatened with an insufficiency of many important materials. This scarcity is reflected in high prices, for which there seems to be no remedy but in the general use of more scientific methods. The failure of our food supply to increase as rapidly as our population calls for a campaign of education; it also appeals strongly to the scientific inventor.

Much food goes to waste, largely because of the expense of transportation and marketing, but also because of its deterioration. Chemical preservatives are looked upon with deserved suspicion. The best preservative is refrigeration. Food kept at temperatures in the neighborhood of forty degrees Fahrenheit can be kept fresh for a long time. Ice is the cheapest material for refrigeration, if it can be used reasonably near to the place where it is cut. But it is a very heavy substance, and to the cost of the transportation of such a bulk is added a very large percentage of waste. Excepting in cities situated in the far north and near good supplies of ice, the refrigeration of great warehouses with ice is almost impracticable. Here the scientific inventor comes to our rescue.

THE MECHANICAL PRODUCTION OF COLD

Many hundreds of years ago, the Egyptians discovered that they could make ice in the open air in hot weather. Their method was quite simple, and depended for its success on the heat of the sun and dryness of the atmosphere in that climate. They would scoop out a shallow hollow in the earth and line it with rice straw. This straw is a poor conductor of heat, and served to protect the vessel of water from the warmth of the earth. A very shallow earthenware vessel was now placed in the hollow upon the straw, and water poured into it. The hot, dry air above it caused the water to evaporate rapidly, and this evaporation produced cold.

Very thin flakes of ice formed around the edges of the vessel. These were collected with much care and used to cool the wine for kings. There has been a great change in the world since these thin wafers of ice were made by cunning slaves to float on the golden cup of wine quaffed by some luxurious Pharaoh. The purpose of artificial refrigeration to-day is to cheapen food for all. But the principle is much the same, although used in a far more effective manner, with other substances than water and by other means than direct evaporation in the air. Although this is such an ancient art, its practical use belongs to our own day, and, indeed, may be said to be still in its infancy. For this reason it is less important that we should describe the different machines now in use, than that we should understand the principle upon which they work.

WHAT MAKES THE COLD IN THE ICE MACHINE?

Water at ordinary temperatures is a liquid. By adding a great deal of heat to it, as in a steam boiler, its state is changed and it is made into steam, when it occupies a much larger volume.

At a boiler pressure of 125 pounds the temperature of the steam will be 344 degrees Fahrenheit, and even at the pressure of the atmosphere the temperature of the water must be 212 degrees Fahrenheit before the process of evaporation can begin. These temperatures are much higher than our average room temperatures of about 70 degrees. So in addition to heating the water, so that its temperature increases to these higher values, a much greater quantity of heat must be supplied to change it into steam. In the same way there can be an equal amount of cooling if this same quantity of heat is taken away from the steam.

Now there are some substances which instead of being liquid at ordinary temperatures, as water is, are in a vaporous form provided they are under sufficiently high pressures. Ammonia is a vapor at 70 degrees Fahrenheit and about 130 pounds pressure. To remove heat from these vapors it is necessary to condense them to liquid form. This may be done artificially without changing the pressure. Then if this pressure is allowed to drop to standard atmospheric pressure, and the liquid is brought in contact with air or any substance at ordinary temperatures, it will take on again the heat of vaporization and in so doing will cool the substance from which the heat is taken to a temperature lower than its usual point.

During both of these processes of condensation and vaporization the temperature of the changing fluid remains the same, the transfer of heat simply causing an alteration in the state of the material.

TWO TYPES OF MACHINE

This is one of the general principles on which the refrigerating machines of to-day depend. These are known as Compression Machines and are the type most commonly used. The other type known as the Absorption Machine works on the principle of some substance like ammonia dissolving in water. Heating a mixture of water and liquid ammonia drives off ammonia vapor. This vapor is condensed by cooling water and is then returned to a vaporous condition by dropping its pressure and coming in contact with the substance to be cooled as in the compression machine. The water is cooled and reabsorbs the ammonia vapor at a low temperature.

The refrigerant most commonly used is ammonia, although to-day the employment of other substances is rapidly growing. Carbonic acid is used to some extent, while most of the small household machines contain sulphur dioxide. Ethyl chloride, methyl chloride, and ether are some of the other mediums employed.

THE PROCESS

The operations taking place in the usual type of ammonia compression machine are as follows: First, the ammonia as a vapor or a mixture of liquid and vapor at a low pressure is compressed in a machine similar to an ordinary air compressor. It leaves this machine completely vaporized and at a high pressure. It is then turned into a coil of pipe surrounded by cold water, where it is entirely condensed to liquid form; the pressure, however, does not change. Next it is allowed to pass through a small opening where the pressure is dropped and a small part of the liquid is vaporized. From here it is brought into contact with whatever it is desired to cool and is completely vaporized by taking heat from this substance. It has now arrived at its original condition and is ready to be compressed again.

The low temperatures obtained by such a machine may be used in various ways. Pipes containing the ammonia may be located around the walls of the refrigerator or cooling room. This is called "direct cooling." The ammonia pipes may pass through a tank containing salt water or brine, which will remain a liquid at very low temperatures, and this may be circulated by a pump through pipes around the refrigerating room. This is "indirect cooling." Or, again, the ammonia may be circulated in such a way that water may be made into ice.

PRACTICAL USES OF ARTIFICIAL COLD

These ice-making plants are rapidly coming into use, especially in those climates where natural ice cannot be produced. Artificial ice is made in two ways, by freezing water placed in cans so that each can will contain a 200 or 300 pound cake of ice, or by immersing metal plates in a tank of water and causing ice to form on these plates in large cakes. Artificial ice is much purer than that frozen naturally, for it is made from distilled water.

The great self-refrigerating warehouses that are now essential at all points where foodstuffs are held for shipment are generally equipped with plants of the style in which brine is chilled by ammonia vapor and piped about the walls of cells, or small rooms. Many of them contain acres of floor space and store huge quantities of meat, eggs, fish, and other rapidly deteriorating food supplies. Another important application of refrigeration is the use on railroads of refrigerator cars for carrying foods of all kinds in a complete state of preservation. By this means perishable foods may be transported, without danger of decay, for long distances.

Artificial household refrigeration is finding wide application throughout all sections of the country. Many large apartment houses are now equipped with a single system which supplies artificial cooling to the refrigerator of each apartment in much the same way that is used in the commercial warehouses. Small domestic machines are being rapidly introduced into private residences and the expense is being reduced so that they may be enjoyed by many not in the wealthy class. Further development along this line of moderate cost with increased efficiency is continuously proceeding. These small machines are mostly of the compression type, driven by electric motors, and in many cases, especially where cheap electricity prevails, they are more economical than ice. A few domestic absorption machines have been developed which need no electric power but in which certain chemicals have to be periodically renewed. These also show a saving over ice. They are all more reliable and uniform in their action, and their cleanliness is another great advantage. Ice is rarely so pure but that it contains harmful and even dangerous disease germs. Most of these small machines are now made in such a compact form that they can be fitted into an ordinary-sized refrigerator and are so completely automatic that they require little or no attention.

ARTIFICIAL COLD FOR COMFORT AND PLEASURE

Refrigerating plants for cooling the air through the hot season have been installed in many public offices, auditoriums, theaters, department stores, and in many factories where it is important that the product be kept at an even temperature regardless of the season of the year, as well as in private houses of wealth.

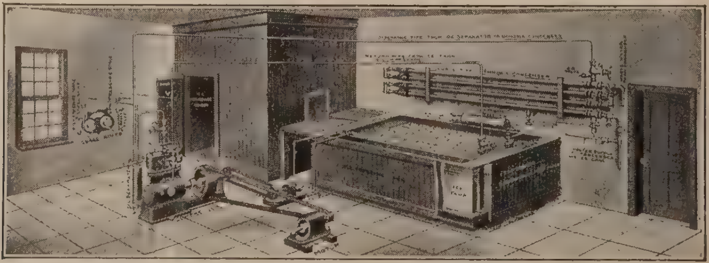
Artificial ice machines are also used to produce ice for skating rinks. A large floor is covered with a network of pipes through which the chilled brine flows. This floor is then sprayed with water in a fine shower, by an ordinary garden hose, and the tiny drops freeze almost as soon as they touch it. When a sufficient thickness is reached, a very perfect surface for skating is produced. In this way ice skating may be indulged in within the torrid zone during the heated spell.

REFRIGERATION ON THE FARM

All farms that deal in dairy products require refrigerating plants of some kind. On most farms ice is readily available, and can be stored in winter in sufficient quantities to meet the year's needs. No machine can equal in economy an ice supply thus obtained. But care must be taken to keep the ice from contact with milk or other food, as it is almost certain to contain some contamination that will endanger the health of those using the milk. On many farms a spring house is still used for cooling milk, and it is often very effective. The spring house, to be most effective, should have good ventilation of the right kind. While direct sunlight should be excluded, there should be ventilation in the roof, or as near it as is practicable. The flow of a constant current of pure air not only sweetens the room, but increases evaporation from the spring and cools the water. It is easy to mistake a damp atmosphere for a cool one. If you find your milk souring in your spring house, take in a reliable thermometer. You will find that the temperature is not as low as you have been led to believe by the darkness and dampness of the air. Put your thermometer in the spring itself. You will see that it is not as cool as it ought to be. That is the worst possible condition for milk, and you need not be surprised at your heavy losses by quick souring. Now put a box of lime and charcoal in a corner of the room, and open a ventilator through the roof and near the floor, in such a manner that there may be a circulation of air. Your spring house, being less damp, may not feel so cool when you enter it; but your thermometer will tell you that it is actually cooler, and if you now try the temperature of the spring, you will find that it has dropped surprisingly. The best and most gratifying test of the improvement will be that your milk will no longer sour so quickly.

COOLING A SPRING IN THE WOODS

What country boy has not his favorite spring somewhere on a woody hillside? You may easily make its waters much cooler by paying attention to the principles we have described. Scoop out a hole about two feet deep and cover the bottom with clean boards. Treat the sides, for a few inches up, in the same manner. The earth contains much heat; but wood is a slow conductor of heat, and will serve as a protection to the water of the spring. Now sprinkle over the boards some clean sand and pebbles, burying them an inch or more. Thus covered they will not rot or become covered with unhealthy green growths. Now arrange an outlet so that the water will remain in slow motion and be kept shallow. You now have a clean, broad, shallow pool, protected from the heat of the earth and in continual gentle motion. This you must protect from the direct rays of the sun, for which purpose nothing can be better than to plant a few small hemlock saplings about it, bending their tops together. Be sure that, while you shut out the sun, you do not shut out the air, which must move freely over the surface of the little pool. Now, let the wonderful forces of Nature work for a short time, and on the next warm day that you visit your pool you will be amazed at the coolness of the water. Such a pleasant experience will be worth far more than the temporary delight which it affords, if it leads to a clearer understanding of the principles of scientific refrigeration, upon which the conservation of food supplies so largely depends.



Courtesy of Remington Machine Co., Wilmington, Del.

COMPLETE PLANT FOR MAKING ICE FROM NATURAL WATER SUPPLY

Operated by an electric motor.

Courtesy of Aberthaw Construction Co.

LAYING TILES ON DOME ROOF OF A STANDPIPE

MACHINE-MADE HOUSES

THUS far we have studied the application of machinery to the making of clothing for man, to his means of travel, to his food supply, and to the spread of knowledge by printing. Machinery is also used in the building of his houses. In Volume IV we treat of the construction of the modern "skyscraper," with its steel frame. Brick-making machinery largely replaces the making of brick by hand. Woodwork is shaped by machinery, effecting a great saving in carpentry and joinery. But the most modern application of machinery to house building is in the manufacture of the parts for concrete houses.

It is little more than half a century since concrete was used in modern Europe for the first time, little more than a quarter of a century since it was first used in America; yet now many of the greatest structures in the world are made of this material. Like many another "new invention," concrete is a very old story. More than a thousand years ago the Romans, who were the builders of their time, used it for aqueducts and bridges, and there much of their work stands to-day, little affected by the lapse of a thousand years.

THE DURABILITY OF CONCRETE

That is one reason why builders are turning to concrete so hopefully — its durability. Wood has been the favorite building material in America for three hundred years, because wood has been plentiful and cheap. Yet wooden structures begin to decay almost from the moment they are finished and need constant renewal. Iron and steel are too expensive. So are bricks, and too slow moving. In concrete, builders are more and more finding the one material which is of great durability, is of low cost, and which lends itself readily to the finer arts of decoration.

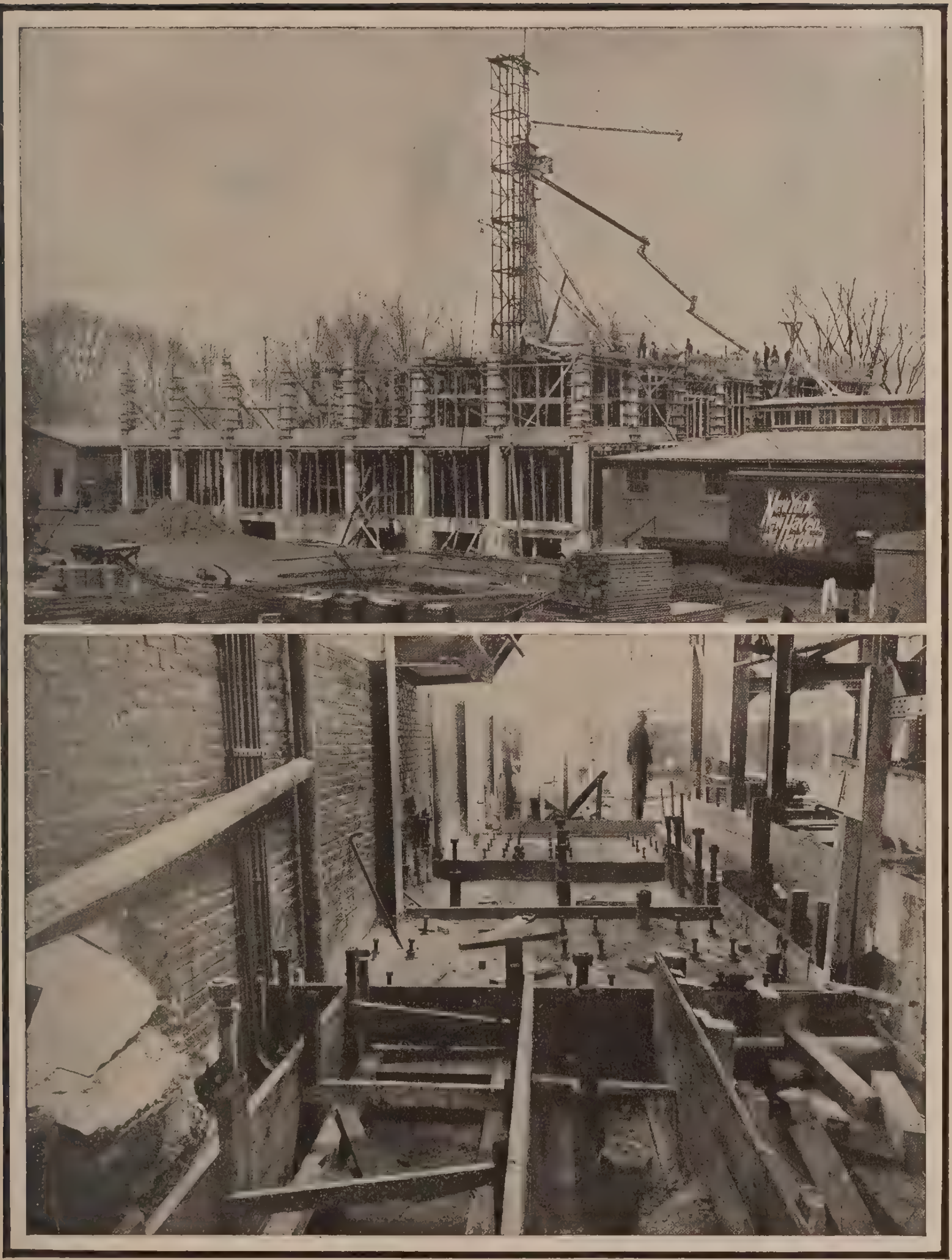
ITS INVENTION AND MANUFACTURE

John Smeaton, who built the first rock Eddystone lighthouse in England and was famous in his time for that feat, is the inventor of the modern form of concrete. In building his lighthouse it was necessary to have a kind of cement which would harden under water. This Smeaton contrived by burning a certain kind of limestone. This was in 1756. In 1818 what was called a natural cement was made in the United States by Canvass White and used in the construction of the Erie Canal. All that was needed was a clayey limestone which contained a certain percentage of iron oxide. The material was crushed and burned in a kiln, the result ground to a powder and kept dry until wanted. Then it was necessary to mix the powder with sand and water, mold it into the shape required, and let it harden or "set." The supply of the natural limestone of the desired kind is limited, however, and later men began to make the Portland cement, as it was called, artificially. In 1890, after the process had been used in America, only 335,500 barrels of Portland cement were made in this country; but since then the industry has grown until we make annually more than a hundred million barrels, and the use is rapidly increasing.

PLASTERING A TILE WALL

The houses in the distance show the bare tiles.

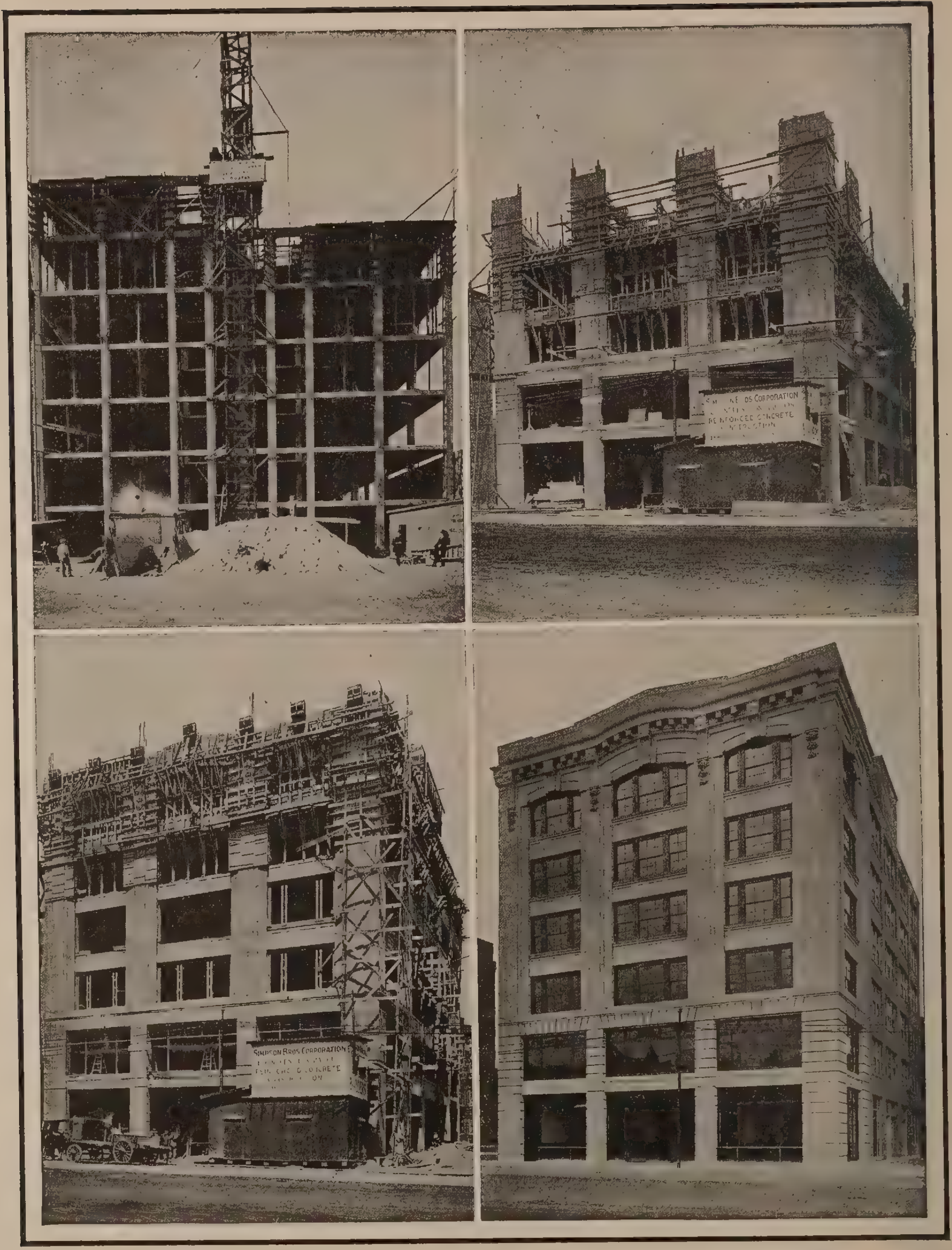
In the manufacture, slag from the great iron furnaces is much used. The raw material is ground into a fine powder and blown into a long iron tube which looks like a huge smokestack lying on its side. Within this stack coal dust blown in with the cement material is burning, making a heat of 2500–3000 degrees Fahrenheit. The cement comes out at the other end of this great tube in clinkers about the size of marbles. These are ground into a very fine powder, and after being stored awhile to "season" the cement is ready for use. Then, mixed with coarse sand and water, it forms a plastic paste which may be molded into the desired



Courtesy of Aberthaw Construction Co.

CONCRETE CONSTRUCTION

Top: Pouring the concrete, which is mixed in the basement and then carried up to the tower in a car, which automatically dumps it into troughs leading down to the molds on the walls or floors. Bottom: Laying concrete foundations for supporting very heavy machinery.


SIMPSON BROS CORPORATION
REINFORCED CONCRETE

A REËNFORCED CONCRETE BUILDING IN PROCESS OF CONSTRUCTION AND COMPLETED shape and, if necessary, reënforced with steel rods to give the finished structure additional strength. The paste soon sets into one of the hardest and most enduring rocks known.

THE WONDERS OF CONCRETE

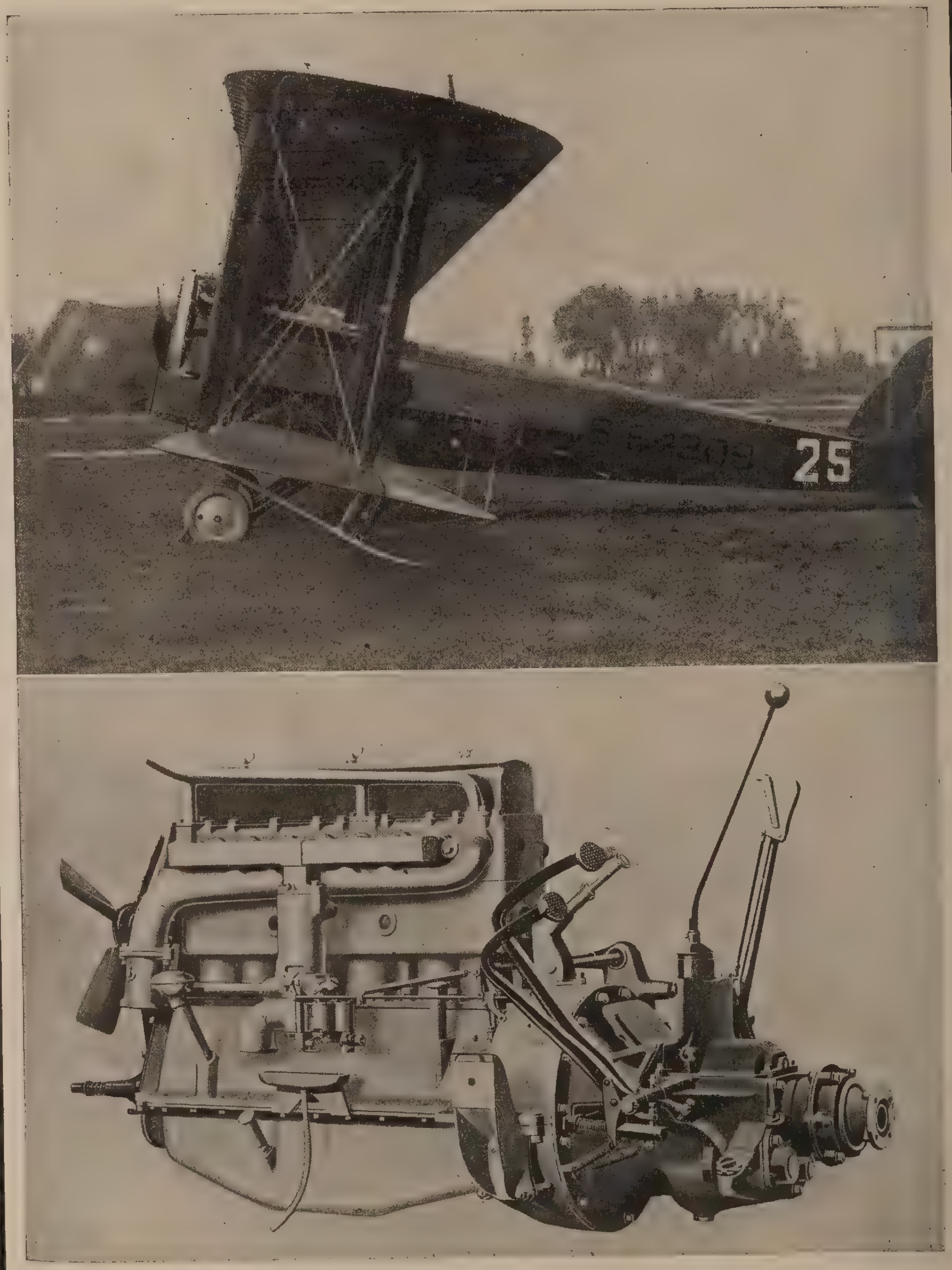
The world's greatest completed concrete structure is the Gatun Locks on the Panama Canal. There are three of these locks, each a thousand feet long, one hundred and ten feet wide, and forty-five feet deep, practically all made of concrete. So massive is the structure that only on certain portions of it is reënforcement necessary. The work required eight million cubic yards of concrete, almost a million tons of cement, and is a far greater achievement than the pyramids of Egypt. This is the most stupendous piece of engineering ever undertaken by man, and if it were not for concrete it would have been almost impossible to finish it.

Concrete is of great use about the home and farm for making floors, walls, and articles like posts, troughs, drains, etc.

Indestructible and fireproof buildings made of concrete are now going up in every great city of the world. It is being used for the foundations of houses, and for steps and sidewalks. By pouring the concrete into the proper molds and allowing it to "set," useful articles of almost any shape can be constructed. By this method park benches, lamp posts, drinking fountains, railroad ties, etc., are made, and there seems to be no end to the uses to which this plastic material may be put.

Concrete is also coming into growing use for road building, as highways paved with this stonelike substance are smooth and durable, and require little care.

A DWELLING HOUSE OF HOLLOW-TILE CONSTRUCTION



Official photo, U. S. Army Air Service; Photo, Buick Company

THE INTERNAL-COMBUSTION ENGINE

As it is used in the airplane, a Martin bomber; and in the automobile, a motor capable of developing a speed of 60 to 70 miles an hour. The photograph shows the left side of the motor with the clutch and control system.

Official Photo, U. S. Army Air Service

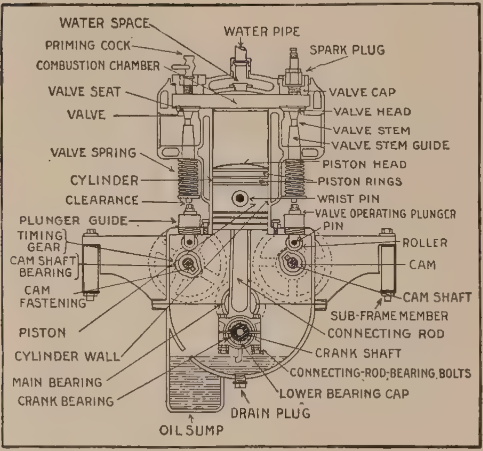
FOKKER MONOPLANE THAT MADE FIRST TRANSCONTINENTAL FLIGHT

THE INTERNAL-COMBUSTION ENGINE AND WHAT IT HAS MADE POSSIBLE

THE AUTOMOBILE, THE MOTOR BOAT, AND THE AIRSHIP

THE successful commercial development of the internal-combustion engine has made possible an entirely new group of machines for furnishing power. The steam engine has been in use for many years. The electric motor in its isolated state, that is, taking current from a storage battery, may be used as yet only under limited conditions. The internal-combustion engine, however, is a complete power plant in itself, built in units of from one to ten thousand horse power, taking up very little space for the power developed, used in an unlimited number of ways in stationary power plants, and furnishing an ideal engine for such machines as the automobile, the motor boat, and the flying machine. Since the successful gasoline engine has become a certainty, these inventions have become possible and practicable. Their development has made miraculous strides, and they are now important factors in our everyday life. Before this type of portable engine was available, they were an impossibility. It is our purpose here to tell in a simple way how an internal-combustion engine looks and works and something about the other important parts of automobiles and flying machines.

We are indebted to the Automobile Journal Publishing Company for the originals from which many of the diagrams on the following pages were redrawn.


WATER SPACE
WATER PIPE
PRIMING COCK
SPARK PLUG
COMBUSTION CHAMBER
VALVE SEAT
VALVE CAP
VALVE
VALVE HEAD
VALVE STEM
VALVE STEM GUIDE
VALVE SPRING
PISTON HEAD
CYLINDER
PISTON RINGS
CLEARANCE
WRIST PIN
PLUNGER GUIDE
VALVE OPERATING PLUNGER PIN
TIMING GEAR
ROLLER
CAM SHAFT BEARING
CAM
CAM FASTENING
CAM SHAFT
SUB-FRAME MEMBER
PISTON
CONNECTING ROD
CYLINDER WALL
CRANK SHAFT
CONNECTING-ROD-BEARING BOLTS
MAIN BEARING
LOWER BEARING CAP
CRANK BEARING
DRAIN PLUG
OIL SUMP

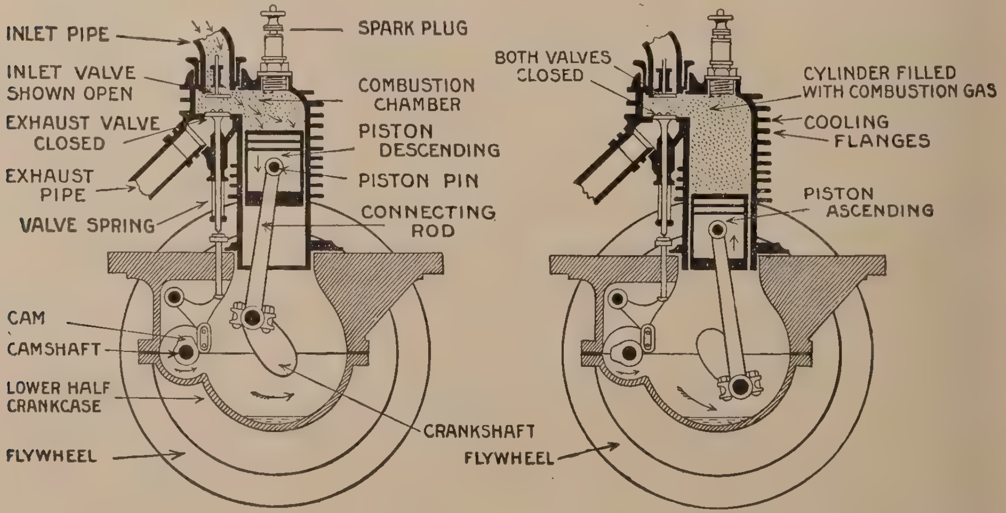
SECTIONAL VIEW SHOWING PARTS OF ORDINARY INTERNAL-COMBUSTION ENGINE

HOW THE POWER IS PRODUCED

The most general source of power is heat. Combustion is what results when any chemical combination produces heat. The element oxygen is always necessary for combustion and is taken from the unlimited supply of air which surrounds us. The other necessary element is known as a "combustible" and may be defined as any substance capable of combining with oxygen to produce heat. The most common of these are carbon and hydrogen, which occur in all common fuels. The speed of combustion depends on the attraction of the combustible element for oxygen, and has a wide variation from the slow formation of rust to the instantaneous explosion of powder. Two of the necessary conditions for complete combustion are the presence of the two elements (some combustible and oxygen) in the proper proportion and the correct temperature.

Carbon and hydrogen occur in various combinations known as "hydrocarbons." When one of these hydrocarbons is brought into the cylinder of an internal-combustion engine mixed with the proper amount of air and raised to the correct temperature (usually by means of an electric spark), instantaneous combustion results and power is produced.

Some hydrocarbons occur as gases while others are liquids. The most familiar of the gases are: our ordinary illuminating gas; a manufactured product made in a retort or furnace and called "producer gas"; natural gas in localities where it is found; and a by-product of the blast furnace known as "blast furnace gas." All these when properly adapted may be used in internal-combustion engines.


INLET PIPE
SPARK PLUG
INLET VALVE SHOWN OPEN
COMBUSTION CHAMBER
EXHAUST VALVE CLOSED
PISTON DESCENDING
EXHAUST PIPE
PISTON PIN
VALVE SPRING
CONNECTING ROD
CAM
CAMSHAFT
LOWER HALF CRANKCASE
CRANKSHAFT
FLYWHEEL
BOTH VALVES CLOSED
CYLINDER FILLED WITH COMBUSTION GAS
COOLING FLANGES
PISTON ASCENDING
FLYWHEEL

FOUR OPERATIONS WHICH TAKE PLACE

The admission stroke.

The compression stroke.

The bulk of these fuels prevents their use in portable engines where much fuel must occupy little space. For this purpose liquid hydrocarbons are employed. Of these, one — gasoline — practically monopolizes the situation. Before a liquid hydrocarbon can be used in an engine it must be changed to a vapor. Gasoline is practically the only instance where this takes place at ordinary atmospheric temperatures. For this reason, if for no other, gasoline will continue to hold the field against all comers despite any considerable increase in price that may come, as long as no other similar fuel has the same characteristic.

Kerosene, which with gasoline is a distillate of petroleum, is another hydrocarbon which has a limited use on some few heavy, slow-speed engines. It will not vaporize, however, much under 400° Fahrenheit, and is therefore not a serious competitor of gasoline. Other hydrocarbons may be used under special conditions but they need not be mentioned here.

THE PRINCIPLES ON WHICH THESE ENGINES OPERATE

The engines in common use to-day for portable work operate on what are called either the "two-cycle" or the "four-cycle" principles. These terms are somewhat misleading, as the true names are "two-stroke-cycle" and "four-stroke-cycle." Whether an engine operates on one of these cycles or on the other, there are four operations which must take place:

First, the explosive mixture of gasoline and air must be drawn into the cylinder of the engine. This is called "admission."

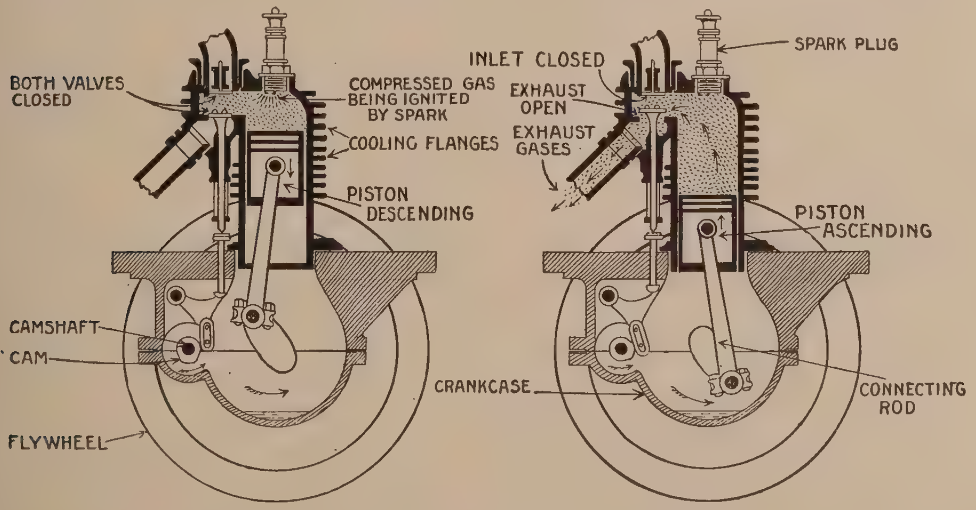
Secondly, this same charge must be compressed to a pressure of about seventy-five pounds per square inch.

Then, the charge is fired by an electric spark, causing an explosion which produces the third or "expansion" process.

Finally, the burned gases must be forced out of the cylinder to make room for another charge. This is the "exhaust."

In the four-cycle or four-stroke-cycle these four events — admission, compression, expansion, and exhaust — occupy four consecutive strokes or two revolutions of the engine. In the two-cycle engine these same events take place in two strokes or one revolution. As this latter engine is only used in very small sizes for stationary work, and in small motor boats, no further reference to it will be made here.

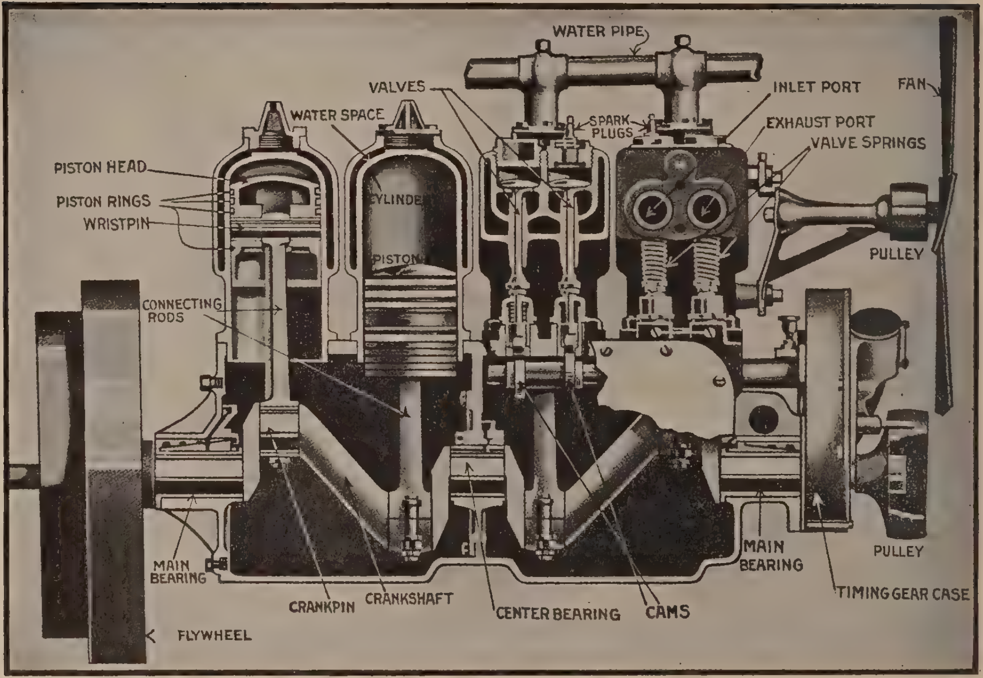
The four operations as they take place in a four-cycle engine are clearly shown in the illustration below. The sectional view of an



IN A FOUR-CYCLE INTERNAL-COMBUSTION ENGINE

The expansion process.

The exhaust.


WATER PIPE
VALVES
WATER SPACE
SPARK PLUGS
INLET PORT
FAN
EXHAUST PORT
VALVE SPRINGS
PISTON HEAD
PISTON RINGS
WRISTPIN
CYLINDER
PISTON
PULLEY
CONNECTING RODS
MAIN BEARING
MAIN BEARING
PULLEY
TIMING GEAR CASE
CRANKPIN
CRANKSHAFT
CENTER BEARING
CAMS
FLYWHEEL

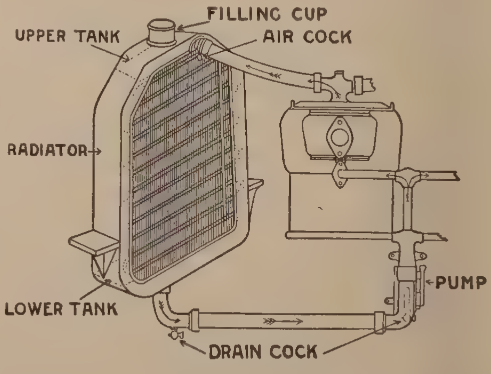
A FOUR-CYLINDER ENGINE

automobile power plant, consisting of a four-cylinder engine with its various accessories, is seen in the illustration at the head of the page. The parts are labeled, so that further explanation is unnecessary. In a four-cylinder, four-cycle engine a firing stroke will occur in some one cylinder every half-revolution, and the order of firing, counting the front cylinder as one, is generally 1—2—4—3. This arrangement will cause a much better running of the engine, for several reasons.

The pistons are long and hollow, of the trunk type. The cranks revolve in an oil-tight case and, dipping into the oil, splash it over the piston, cylinder, connecting rod, bearings, etc.

THE CYLINDER TEMPERATURE, AND AIR COOLING

The temperature in the cylinder when the explosion is taking place is somewhere around 2500 to 3000 degrees Fahrenheit. Of course much heat is immediately radiated, but, even with this, more useful work is done for the amount of heat supplied in a gas engine than in a steam engine. In order to keep this temperature from rising so that it interferes with the operations in the cylinder, the upper part of the cylinder is water-jacketed to remove the heat from the metal walls as fast as it is generated. With motor boats the supply of


FILLING CUP
UPPER TANK
AIR COCK
RADIATOR
PUMP
LOWER TANK
DRAIN COCK

PARTS OF WATER-COOLING SYSTEM USING A PUMP

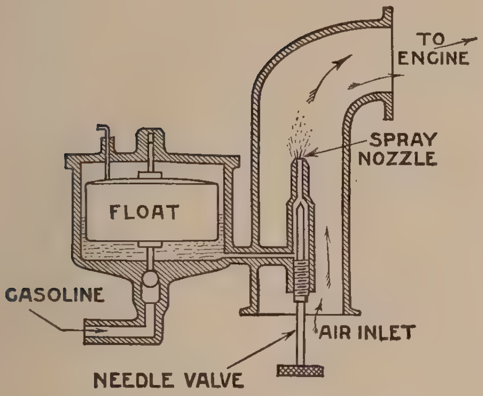

TO ENGINE
SPRAY NOZZLE
FLOAT
GASOLINE
AIR INLET
NEEDLE VALVE

DIAGRAM OF A FLOAT-FEED CARBURETOR

water is, of course, unlimited, but with automobiles, if the natural circulation system is used, the hot water passes from the top of the cylinder jackets to the top of the radiator, where it is cooled by dividing it up into small sections and bringing each section into contact with the cooling action of moving air. In this system the circulation is caused by the difference in temperature of the water. In the other system the water is moved by the action of a pump. See diagram on opposite page.

In some special types of engines air cooling is used, as with motorcycle engines and most flying-machine engines. This method of cooling is adapted to cases where the cylinders are exposed to swiftly moving air.

The explosive mixture is allowed to pass to and from the engine cylinder through conical-shaped valves, arranged two for each cylinder, the inlet valve for admitting the charge and the exhaust valve for allowing the burned gases to pass out. These valves are actuated by cams arranged on one or two cam shafts which are driven from the main engine shaft at one half its speed. This is to cause the valves to open at the proper time.

WHAT DOES THE CARBURETOR DO?

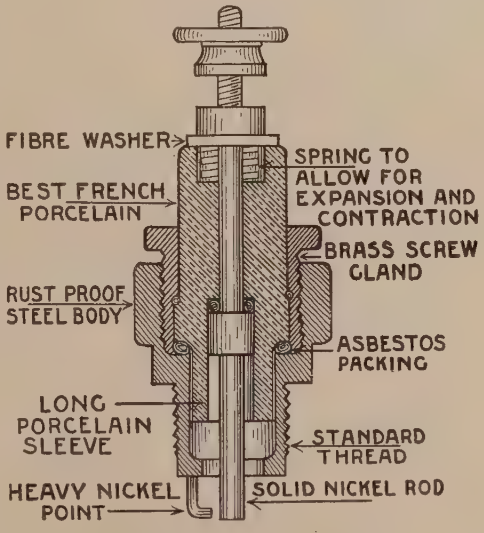
In order that the explosive mixture shall arrive in the cylinder in perfect form, the gasoline must be vaporized: it must be mixed with air and the proportions must be properly adjusted at all engine speeds. All this is done by the carburetor. The illustration shows diagrammatically how such a carburetor works.

Gasoline flows by gravity from a storage tank to the float chamber, where the level is automatically kept constant by the float valve, which shuts off the supply entirely when the engine is stopped. Air is drawn in by the suction of the engine and, passing around the spray nozzle, picks up the proper amount of gasoline, in the form of a finely divided spray, and becoming thus an explosive mixture, passes into the engine cylinder. The quantity of gasoline may be adjusted to the proper amount by the needle valve. In most carburetors an auxiliary air valve is provided which opens at the higher engine speeds, providing more air and keeping the proportions of the mixture correct.

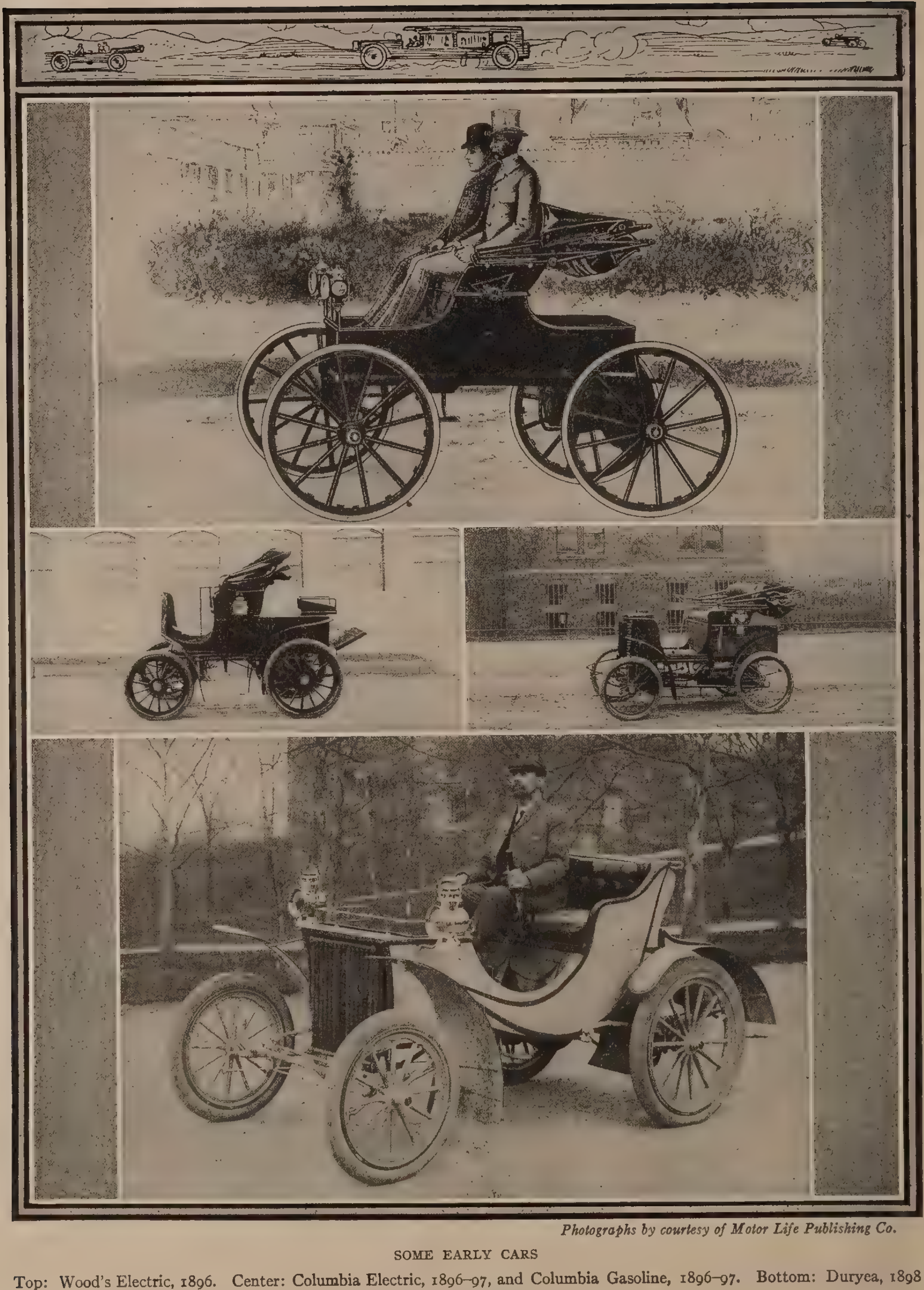
HOW THE CHARGE IS IGNITED

The explosive charge, having been admitted to the cylinder and compressed, is fired by an electric spark which occurs at just the proper moment.

The usual system for a single-cylinder motor is seen in the drawing on page 122. Its action


FIBRE WASHER
BEST FRENCH PORCELAIN
SPRING TO ALLOW FOR EXPANSION AND CONTRACTION
BRASS SCREW GLAND
RUST PROOF STEEL BODY
ASBESTOS PACKING
LONG PORCELAIN SLEEVE
STANDARD THREAD
HEAVY NICKEL POINT
SOLID NICKEL ROD

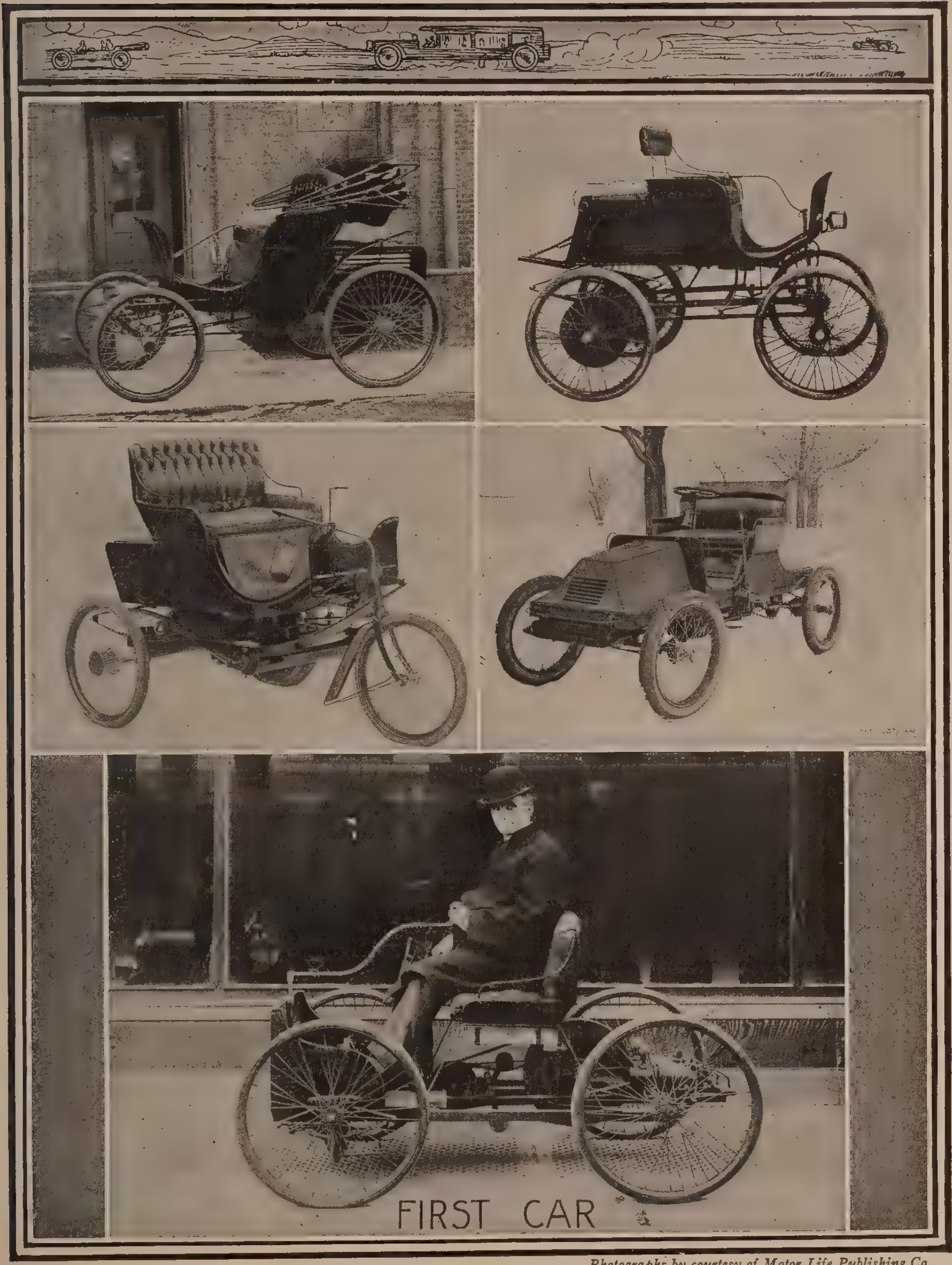
CONSTRUCTION OF THE SPARK PLUG



Photographs by courtesy of Motor Life Publishing Co.

SOME EARLY CARS

Top: Wood's Electric, 1896. Center: Columbia Electric, 1896–97, and Columbia Gasoline, 1896–97. Bottom: Duryea, 1898 (three cylinders).

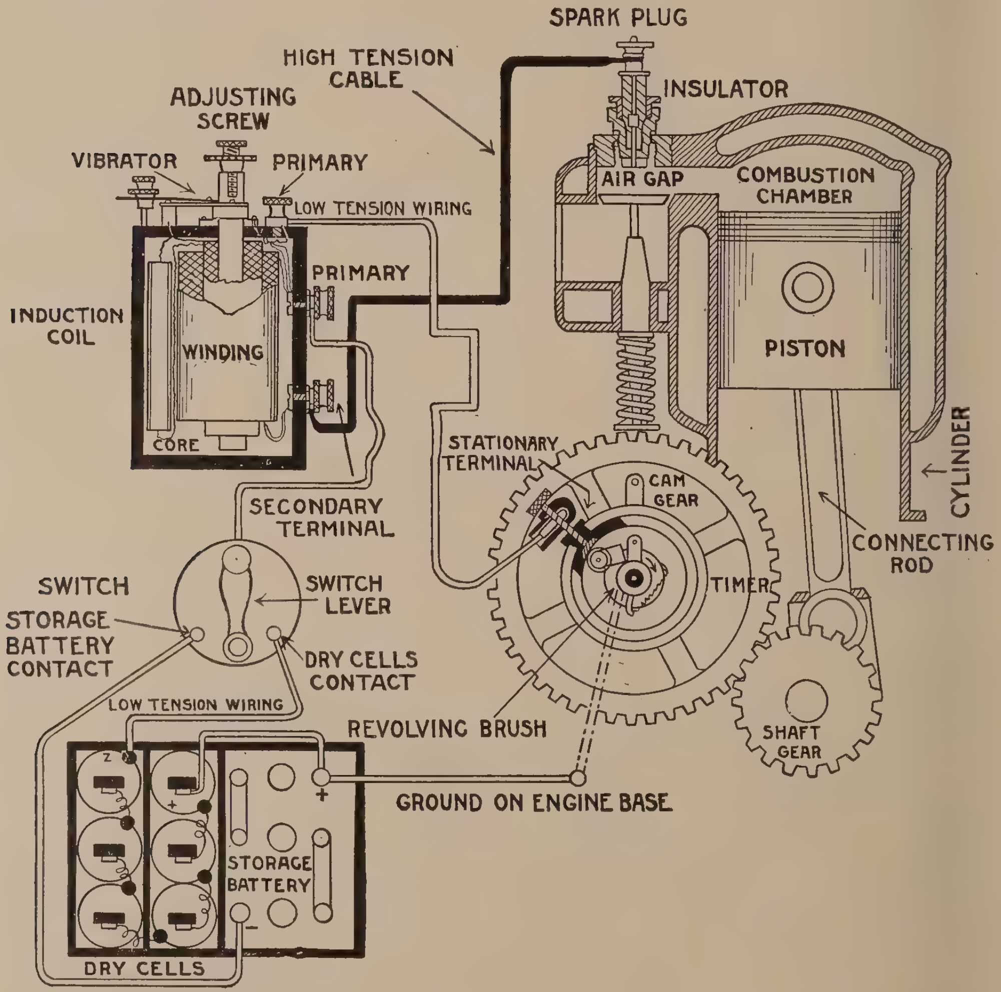


Photographs by courtesy of Motor Life Publishing Co.

SOME EARLY CARS

Top: Winton, 1898, and Waverly Electric, 1898. Center: Knox three-wheeler, 1899, and Stearns, 1899–1900. Bottom: First Ford, 1903.

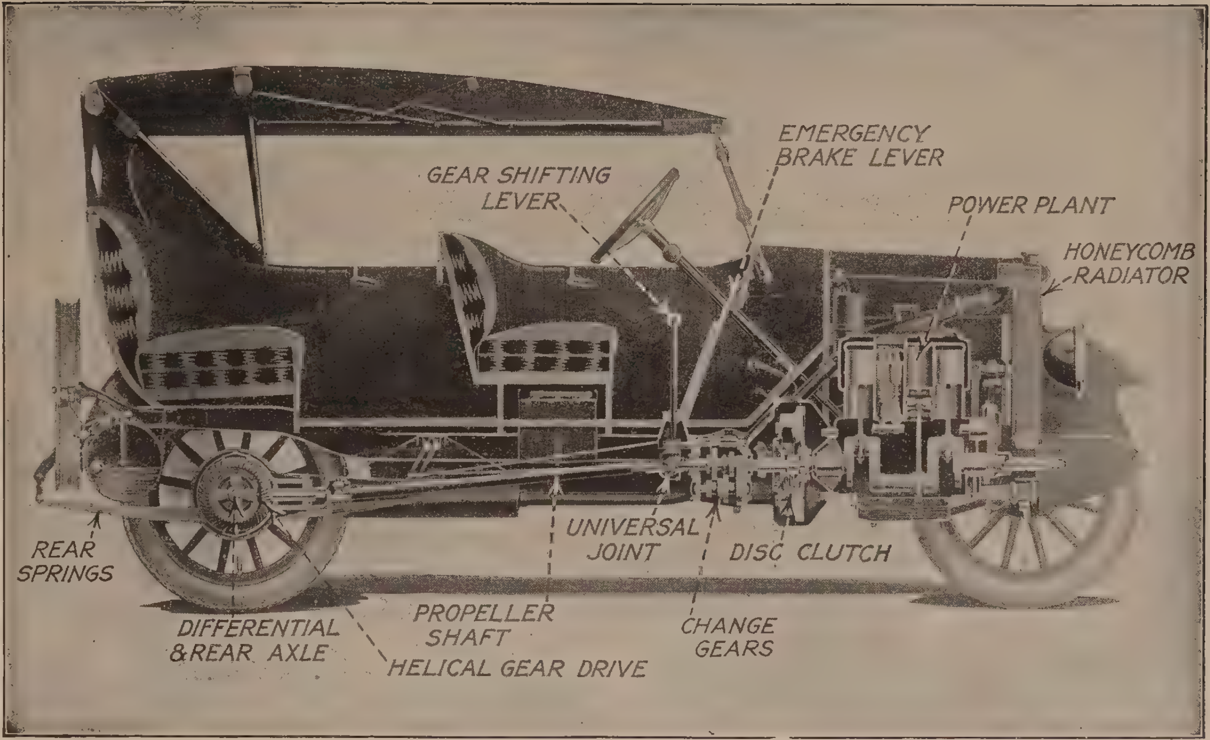
is briefly as follows: Current is supplied either from the dry cells or the storage battery. It is what is called a "low-tension" current and has a pressure of about six volts. From here it passes through the switch to the induction coil, where by means of the proper construction a current with a very high voltage is induced. This voltage, which is probably about twenty thousand volts, is great enough to cause a spark of sufficient intensity to ignite the charge to jump across an air gap introduced in the top of the cylinder by the spark plug. The high-tension current then returns to the battery by way of the metal of the engine and the ground wire.


SPARK PLUG
HIGH TENSION CABLE
ADJUSTING SCREW
INSULATOR
VIBRATOR
PRIMARY
LOW TENSION WIRING
AIR GAP
COMBUSTION CHAMBER
PRIMARY
INDUCTION COIL
WINDING
PISTON
CORE
STATIONARY TERMINAL
CAM GEAR
CYLINDER
SECONDARY TERMINAL
CONNECTING ROD
SWITCH
SWITCH LEVER
TIMER
STORAGE BATTERY CONTACT
DRY CELLS CONTACT
LOW TENSION WIRING
REVOLVING BRUSH
SHAFT GEAR
Z
+
+
GROUND ON ENGINE BASE
STORAGE BATTERY
-
DRY CELLS

JUMP-SPARK IGNITION SYSTEM

The primary current after doing its work in the induction coil passes to the timer—which is simply a revolving switch arranged to open and close the circuit at the proper time—and then back to the battery.

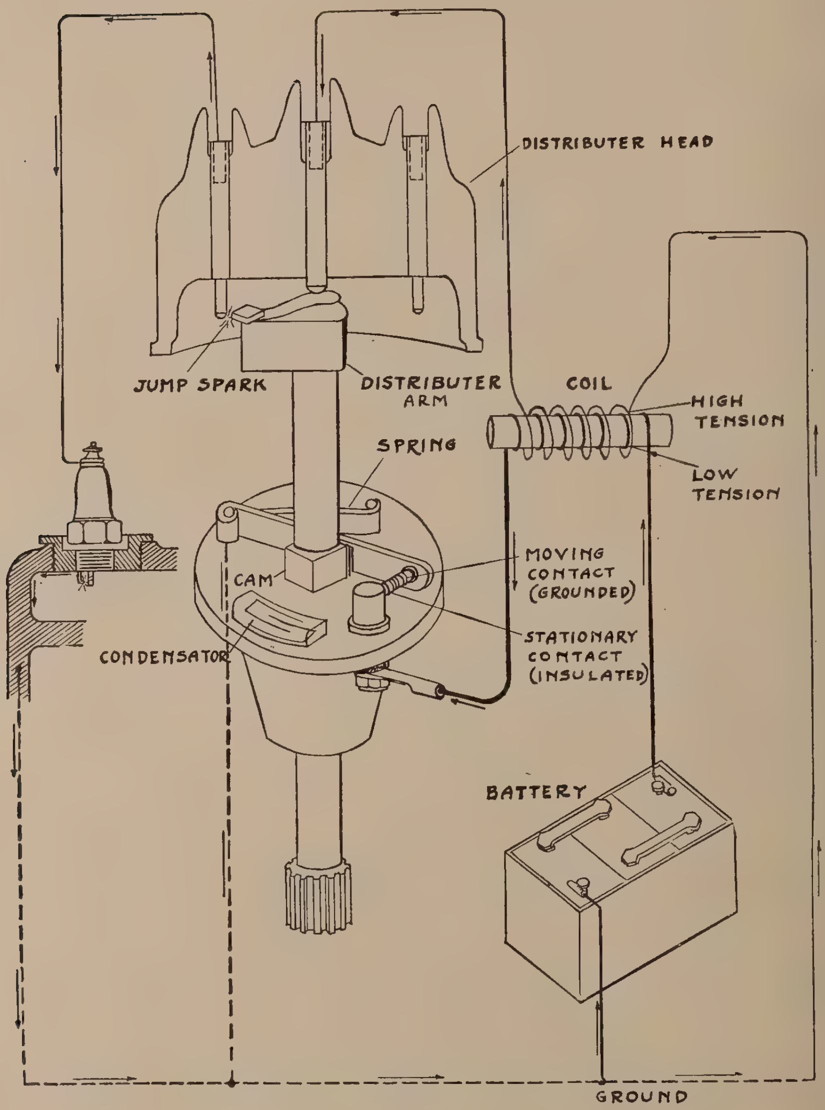
The magnetic vibrator on the end of the coil is a device for intensifying and prolonging the


EMERGENCY BRAKE LEVER
GEAR SHIFTING LEVER
POWER PLANT
HONEYCOMB RADIATOR
REAR SPRINGS
UNIVERSAL JOINT
DISC CLUTCH
PROPELLER SHAFT
CHANGE GEARS
DIFFERENTIAL &REAR AXLE
HELICAL GEAR DRIVE

From Hobbs, Elliott and Consoliver's "Gasoline Automobile," published by McGraw-Hill Book Company, Inc., New York.

SECTION OF A COMPLETE AUTOMOBILE

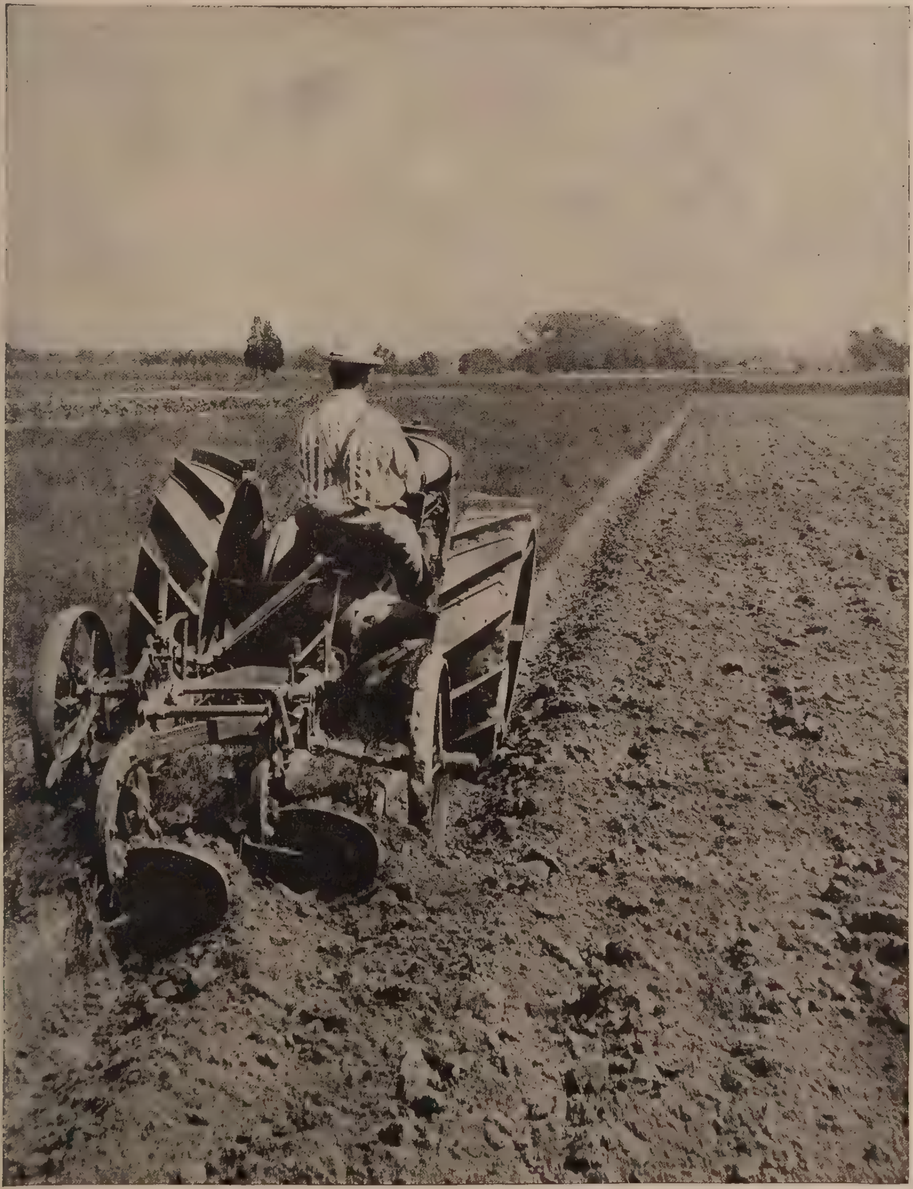
From this diagram the names of the parts of an automobile and their relation to one another may be seen.


DISTRIBUTER HEAD
JUMP SPARK
DISTRIBUTER ARM
COIL
HIGH TENSION
LOW TENSION
SPRING
MOVING CONTACT (GROUNDED)
CAM
CONDENSATOR
STATIONARY CONTACT (INSULATED)
BATTERY
GROUND

TYPICAL BATTERY IGNITION SYSTEM FOR A MULTICYLINDER ENGINE

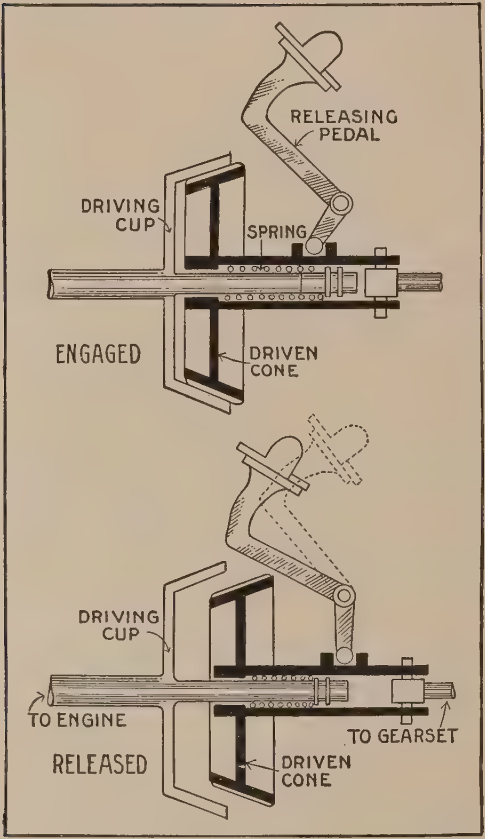
spark. This, however, is at present used only on single-cylinder engines, the Ford automobile engine, and perhaps some of the two- and three-cylinder marine engines of small power.

While at one time the common method of supplying current for portable engines of four, six, and more cylinders was the magneto, which is a form of mechanical generator of electricity similar to the dynamo, its use to-day is confined to some trucks and tractors and some airplane engines. The present universal supply is the storage battery, which is charged by a dynamo driven by the engine. The modern electric starting and lighting systems used by all pleas-



Copyright, Ewing Galloway, N. Y.

PLOWING WITH FORDSON TRACTOR


RELEASING PEDAL
DRIVING CUP
SPRING
ENGAGED
DRIVEN CONE
DRIVING CUP
TO ENGINE
RELEASED
TO GEARSET
DRIVEN CONE

HOW A CONE CLUTCH WORKS

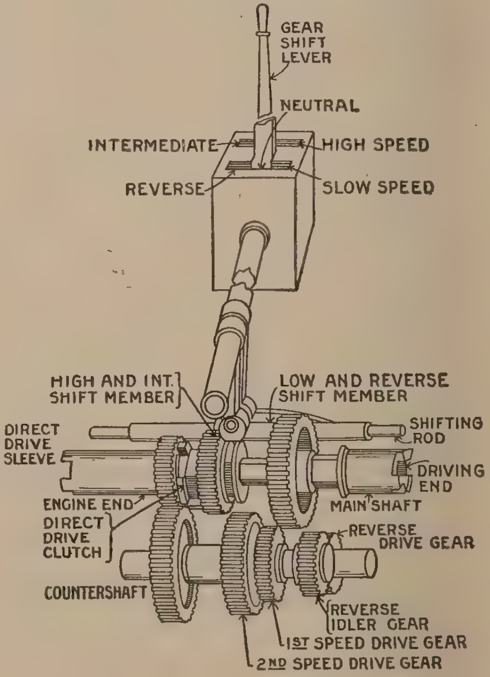
ure automobiles and some trucks require a storage battery to supply the current, and as the amount of electricity used by the ignition system is very small, it may be taken from the battery without being noticed.

The battery ignition system as commonly used for engines having four or more cylinders is shown on page 124. The induction coil, however, is without the vibrator shown on page 122. The proper design of the coil takes care of the lack of vibrator.

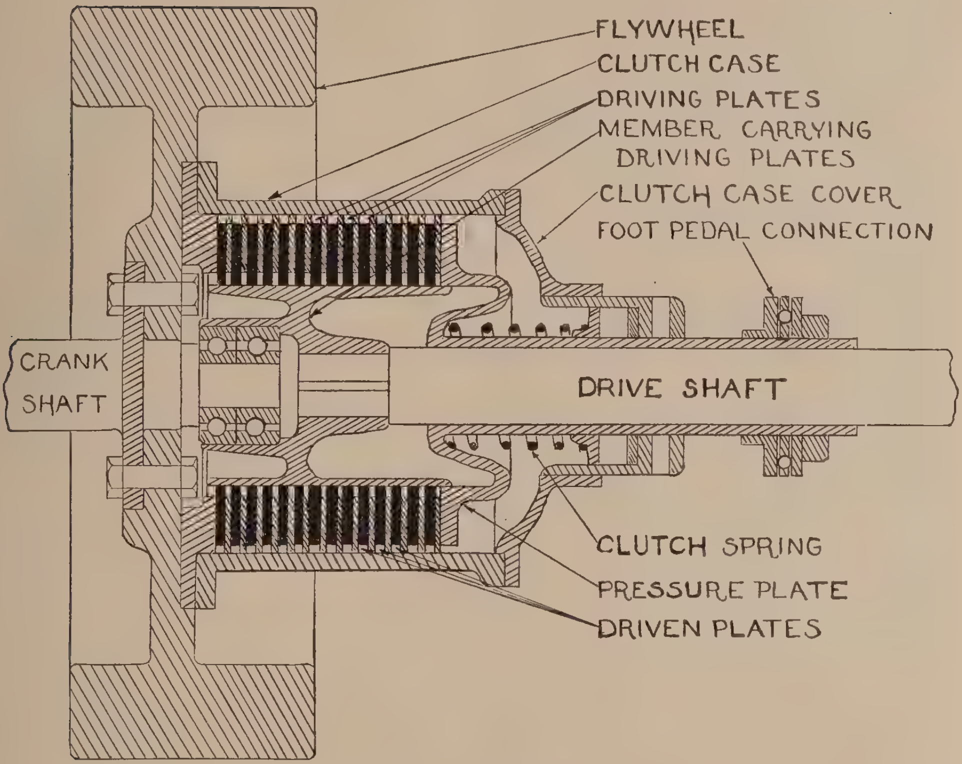
With more than one cylinder the use of a coil makes it necessary to distribute properly the secondary or high-tension current to the various cylinders. This is done by the secondary distributer, which takes the high-tension current from the coil and sends it to the different spark plugs in the proper order. The great improvements in coil and distributer design over those in use before the magneto era are some of the reasons for the wide use of this system at present.

WHAT IS A CLUTCH?

It is quite necessary with automobiles to stop the motion of the car at times and yet to keep the engine running. To accomplish this the engine crank shaft has on its rear end a flywheel with a broad and heavy rim turned to a conical shape inside. Close to this on the end of the shaft, connecting the engine with the gear set, is the clutch plate, a heavy disk with a broad edge so shaped as to fit the inside of the flywheel. The clutch plate is faced with leather. A powerful spring presses the plate into the flywheel, and the resulting friction, preventing any slip, causes the clutch plate shaft to turn with the engine. The friction of the clutch is controlled by a foot pedal which, when de-


GEAR SHIFT LEVER
NEUTRAL
INTERMEDIATE
HIGH SPEED
REVERSE
SLOW SPEED
HIGH AND INT. SHIFT MEMBER
LOW AND REVERSE SHIFT MEMBER
DIRECT DRIVE SLEEVE
SHIFTING ROD
DRIVING END
ENGINE END
MAIN SHAFT
DIRECT DRIVE CLUTCH
REVERSE DRIVE GEAR
COUNTERSHAFT
REVERSE IDLER GEAR
1ST SPEED DRIVE GEAR
2ND SPEED DRIVE GEAR

PARTS OF A SELECTIVE SLIDING-GEAR TRANSMISSION


FLYWHEEL
CLUTCH CASE
DRIVING PLATES
MEMBER CARRYING DRIVING PLATES
CLUTCH CASE COVER
FOOT PEDAL CONNECTION
CRANK SHAFT
DRIVE SHAFT
CLUTCH SPRING
PRESSURE PLATE
DRIVEN PLATES

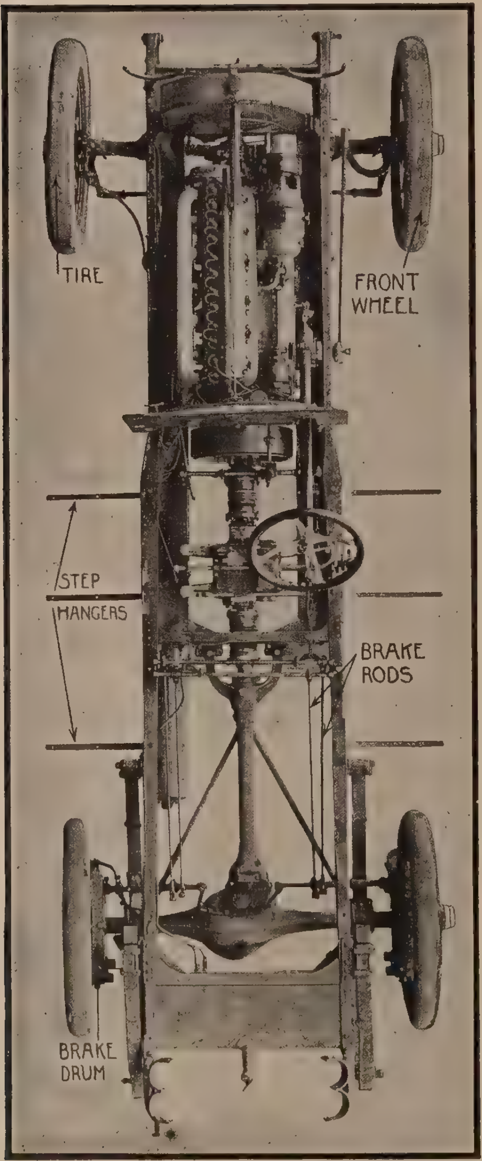
MULTIPLE DISC CLUTCH

pressed, disengages the clutch, stopping the car and allowing the engine to run free.

The multiple disc clutch here shown is a form which is in very general use at the present time. The principle of operation is the same as that of the cone clutch. The clutch surface, however, instead of being confined to one plate is distributed among a number of discs (usually flat) of smaller diameter. There are two sets of these, the driving and the driven, arranged in pairs and all engaging simultaneously. A spring acts as in the cone clutch to keep the driving and driven discs in contact except when the spring is compressed by depressing the foot pedal. This distribution of surface allows the size of the clutch to be less than the other types; also when the plates engage, their slipping one on the other before they come tightly in contact causes a smooth starting without jerks. The discs may or may not run in oil. With the discs running in oil two kinds of metal, like bronze and steel, are used. When there are dry discs one set is usually faced with some form of asbestos composition while the other is of steel.

CHANGING SPEEDS WITH GEARS

It is also necessary in driving an automobile to be able to run at all speeds, from a barely perceptible motion in a crowded street to fifty or sixty miles an hour on a race track. Now the speed of an internal-combustion engine can be varied only within small limits, and therefore some device must be provided whereby the speed of the engine may be kept the same, while the speed of the car is varied within wide limits. This is usually done by what is called a



THE CHASSIS OF A SIX-CYLINDER AUTOMOBILE

By the chassis of an automobile is meant everything below the body of the car. This divides itself naturally into two parts: the power plant, consisting of the engine, muffler, cooling system, oiling system, gasoline supply and feeding system, ignition system, and clutch; and the running gear, which includes the transmission, main driving shaft, differential, front and rear axles, wheels, frame, springs, steering gear, and brakes.

"sliding-gear transmission," one form of which is shown on page 126. If a small-toothed gear is made to drive a large-toothed gear, the speed of the larger will be less than that of the smaller. This is the principle made use of in the gear transmission. The high speed is obtained by driving direct through no gears. The intermediate, low, and reverse are secured by sliding different combinations of gears into mesh with each other and so producing the required motions.

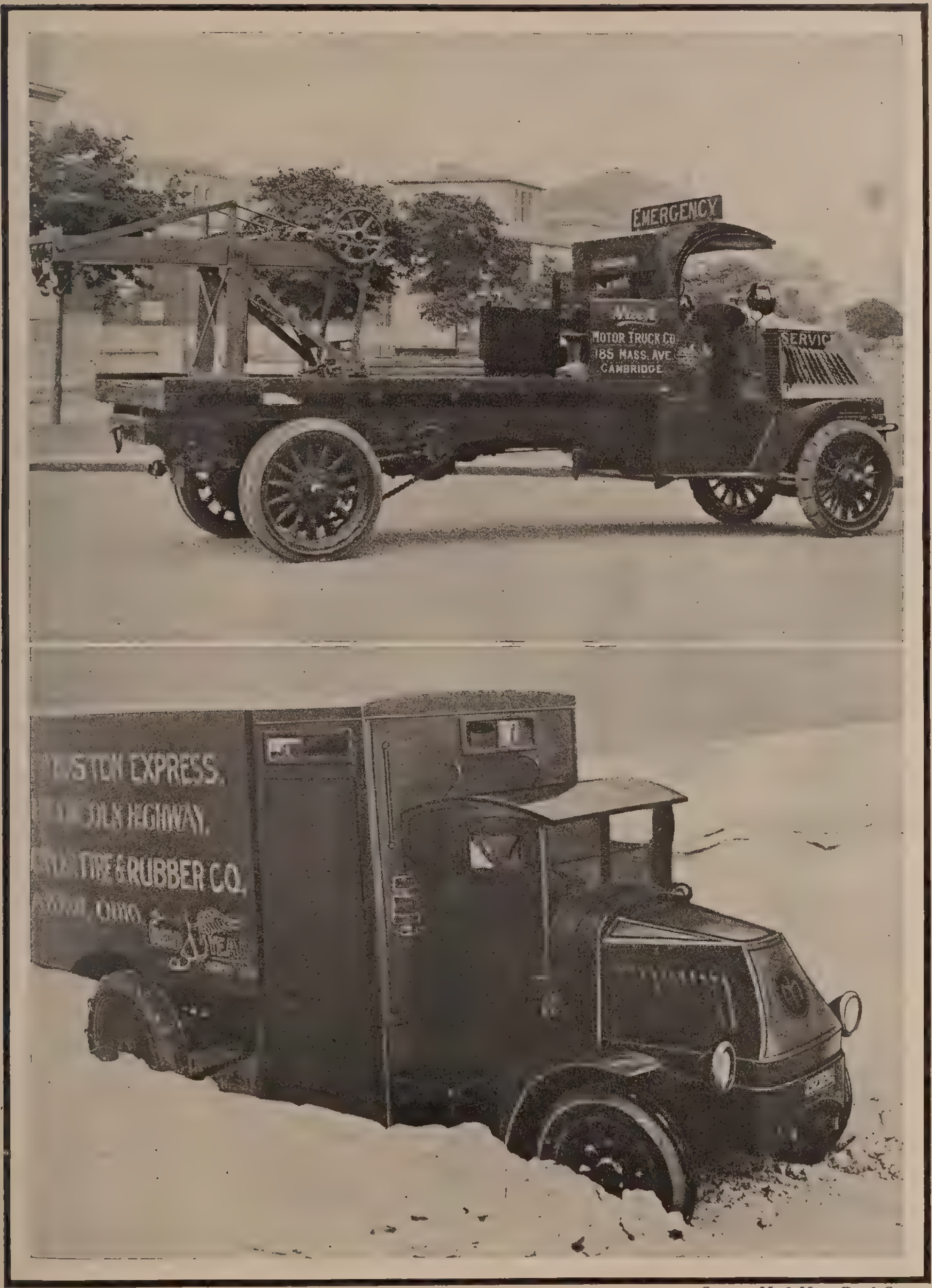
THE DIFFERENTIAL

When a vehicle turns a corner, obviously the outside wheel must travel faster than the inside wheel. In an ordinary horse-drawn carriage, the rear axle does not turn and the rear wheels revolve on the ends of this axle. Therefore each may travel at its own speed without disturbing the other. In most automobiles, however, the rear axle must turn, as it is through this that the power is transmitted from the engine. The axle is therefore divided in the middle and a rear wheel is made fast to each outer end so that the axle and wheels turn together. The two parts of the axle are connected by a device made up largely of gears, called a "differential" or "compensating" device. This is so made that it allows the two wheels to run at different speeds and yet the engine delivers the proper amount of power proportionately to each wheel whatever its speed.

BRAKES AND MUFFLER

Each automobile must, by law, be provided with two independent sets of brakes, so that if one is out of order the other may be used. These generally act on a band just inside of the rear wheels and are controlled, one by a foot pedal, and the other by a lever.

If the gases after doing their work in the engine cylinder were allowed to pass directly into the atmosphere, a very loud noise would result, the action being similar to the report of a gun. The muffler, which is required by law, breaks up the solid stream of gas into small parts and at the same time reduces the pressure gradually, thus doing away with the noise. By proper designing, the exhaust from a muffler may be made practically noiseless.


EMERGENCY
MOTOR TRUCK CO.
185 MASS. AVE.
CAMBRIDGE
SERVIC
STON EXPRESS.
COLN HIGHWAY.
TIRE & RUBBER CO.
OHIO

Courtesy Mack Motor Truck Co.

AUTO TRUCKS

Above: Truck equipped for rescuing disabled automobiles, with crane at rear, operated by truck engine, capable of lifting five tons. Below: One of fleet traveling winter and summer between Ohio and Massachusetts.

THE MOTOR TRUCK

When automobiles are used for industrial purposes, such as hauling merchandise or freight, they are termed commercial cars or trucks. These may differ from the pleasure car only in the body, both using the same chassis. In most cases, however, while the main features of the engine are the same, the whole construction is heavier and stronger than for a pleasure car and the gear ratio regulating the speed of the rear wheels with respect to that of the engine is so arranged that slow speeds and great drawing power are obtained. These and other facts make the manufacture of trucks essentially a separate industry. Owing to the difference in driving conditions many of the details of truck construction differ widely from similar features in pleasure cars. With the exception that most truck engines still use the hand crank for starting, the power plant exhibits the same wonderful improvement in design and adaptation for its work that the pleasure-car engine does.

Much has been done in improving body design and many forms have been specially built for particular uses — trucks with derricks for hoisting heavy loads, trucks with provision for elevating the bodies for coal delivery, and many others. From a commercial point of view we could do without the telephone almost as easily as without the motor truck.

THE "JITNEY 'BUS"

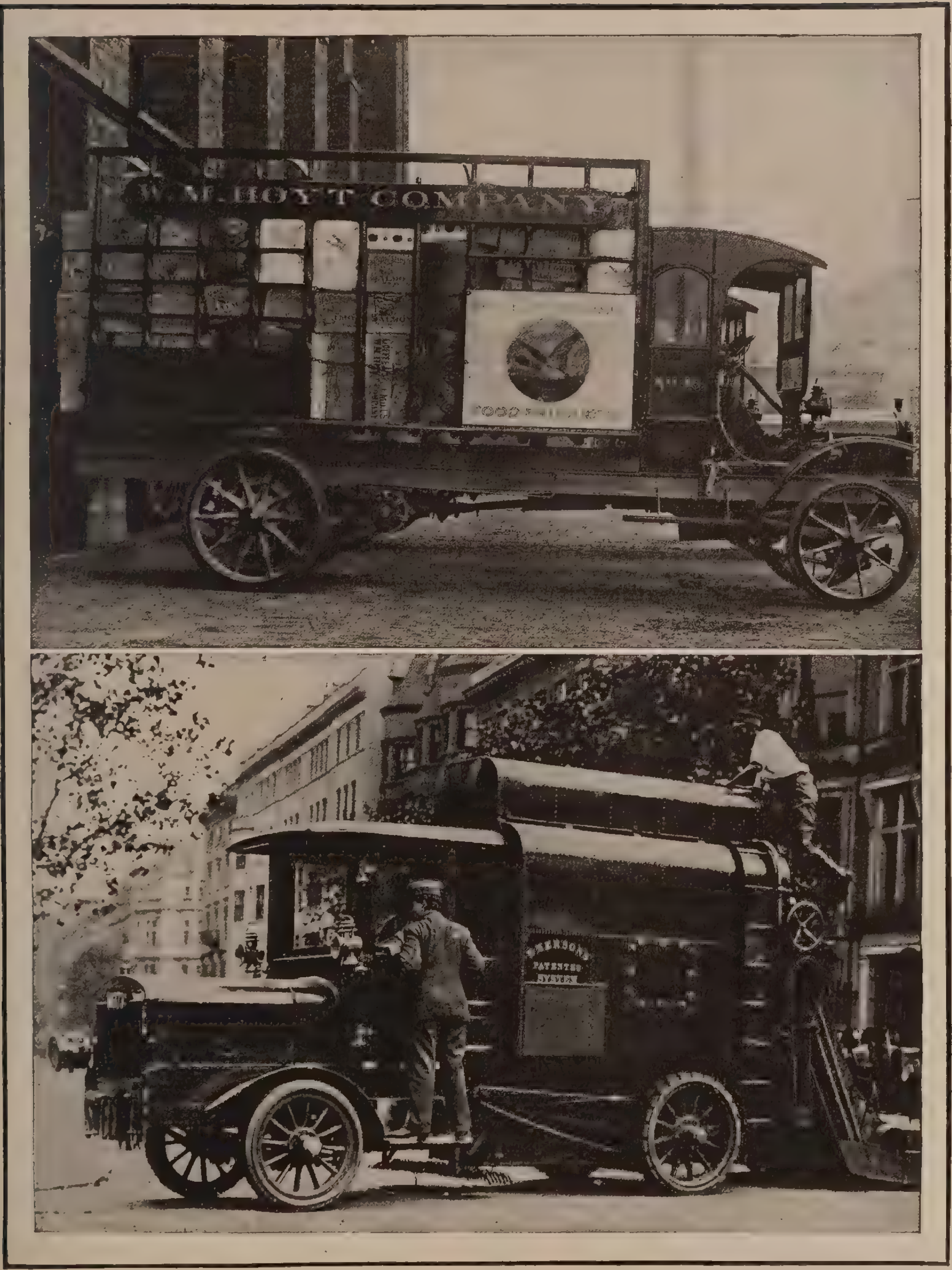
With the development of the automobile to such a load-carrying capacity, there has come the appearance on our highways of the automobile omnibus, popularly known as the "jitney 'bus." These passenger-carrying automobiles perform a unique service, since they are not confined as are street cars and trains to a system of tracks. This freedom of movement makes them especially useful in rural districts, where an excellent, regular service may be maintained over considerable areas. In the towns they enter into competition with the street railways, often covering, under municipal regulation, routes not already served. They are invaluable in transporting school children to centrally located schoolhouses.

THE MOTOR BOAT AND THE HYDROPLANE

In describing with such care the working of the automobile, we have made it less necessary to go into detail concerning the working parts of the motor boat. Most motor boats use what is called the automobile type of engine, although many very small boats run quite successfully with single-cylinder engines of a type that is no longer used for automobiles. A boat engine does not require the muffling so necessary on an automobile. It is only necessary to allow the cylinders to discharge their burned gases under water to muffle effectually the explosions. Nor does a boat engine require the differential that we have seen to be so essential to the success of the automobile. The gearing is far simpler and rarely allows for more than one speed forward and one backward. The regulation of the supply of gas is sufficient for all other speed variations which the conditions of boating require.

But if the boat engine can dispense with many of the complications of the automobile, it should not be thought that it has not in its turn developed according to its own special needs. The engine of a high-power racing motor boat is a wonderful piece of mechanism, often employing as many as twenty-four cylinders, carefully balanced, and each cylinder timed to explode its charge with the most exact care. For if the timing of a many-cylindered engine is not perfect, one cylinder will be found to be working against the others, at some part of its stroke. On the whole, it is possible, because of many minor conditions, to secure higher power from the boat engine than from the road engine. Of course, no motor boat will make the speed of a fast automobile, but that is because of the greater resistance of the water to its progress, and not because of any deficiency of power and mechanism. The popularity of the motor boat is so great that of late the majority of pleasure boats are equipped with these light, convenient, and speedy engines.

One of the latest types of motor boats, which offers something between boating and flying for those daring persons for whom ordinary motor boating is not sufficiently exciting, is the hydroplane. This is a flat-bottomed boat with


M. HOYT COMPANY
FOOD PRODUCTS
EMERSON'S
PATENTED

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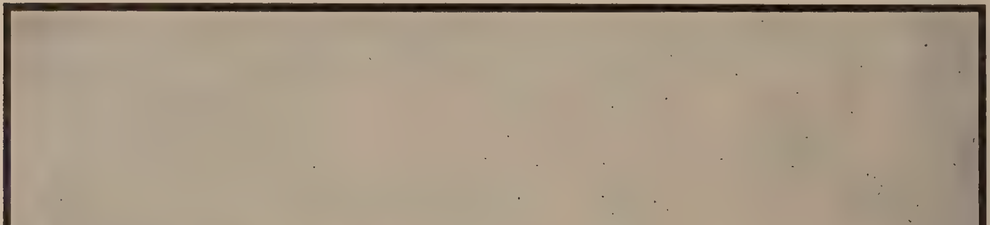
AUTO TRUCKS

Above: One of the commercial trucks which makes for prompt food distribution. Capacity, three tons. Below: An Auto Street Cleaner.

several thin, flat metal surfaces attached to the bottom in such a way that they slant downward toward the stern with their thin edges at right angles to the boat's motion. The effect of these planes is to cause the boat to rise in the water as the speed increases until at full speed the entire bottom is almost wholly above the surface, the planes and propeller being practically the only parts remaining in the water. By this means the friction of the water against the sides and bottom of the boat is avoided, allowing powerful engines to drive such a hydroplane at a speed of fifty or sixty miles an hour.

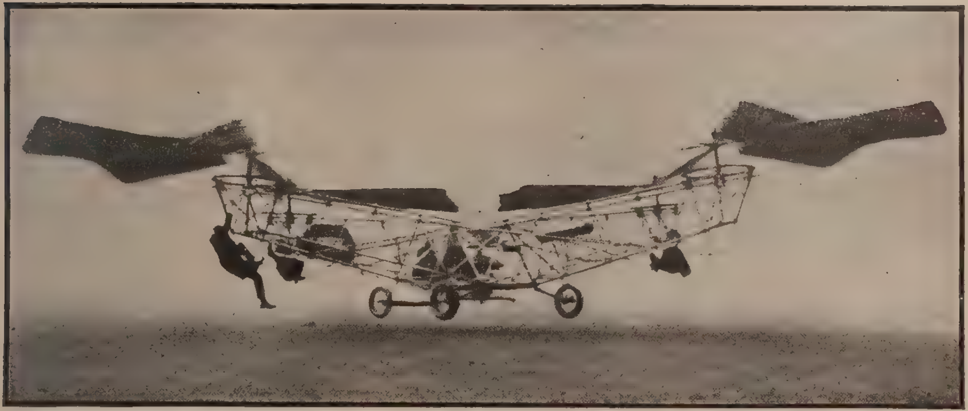
PERFECTING THE GASOLINE ENGINE

The whole trend of internal-combustion-engine design for portable work has been toward simplicity, economy of fuel, and strength combined with light weight, and as the engine is used to-day in the automobile it has reached a high degree of perfection. When, however, man's ideas in regard to flying through the air began to assume a practical form, it was found that the gasoline engine as used in the automobile must be taken a step farther toward the perfect engine before it would be fit for use in a flying machine. The effect of the war was to concentrate effort in this direction, and as a result the aëro engine of to-day is an efficient, reliable machine; an achievement that it would have taken years of ordinary conditions to accomplish. Improvements are still being made, and in reading the next section it should be borne in mind that progress in navigating the air depends in a very large measure on the weight, the economy of fuel, and the reliability of the gasoline motor.



Wide World Photo

BYRD'S TRI-MOTOR FORD PLANE, FOR ANTARCTIC EXPLORATION



Official Photo, U. S. Army Air Service

A HELICOPTER RISING VERTICALLY BY MEANS OF REVOLVING PROPELLERS AT ENDS

THE NAVIGATION OF THE AIR

THE STORY OF ITS DEVELOPMENT FROM THE BALLOON THROUGH THE DIRIGIBLE AND THE LATEST AIRSHIPS

THE gasoline engine, so light in weight and using so perfect a fuel, has made possible the navigation of the air. Through it man's dream of the centuries is realized, for man has planned and hoped and dared and died in attempts to navigate the air for no one knows how long. In the old Greek myth Dædalus and his son Icarus are fabled to have flown by means of wings fastened on with wax. But the increasing heat of the sun melted the wax, and one of these mythical early airmen fell to the ground and was killed. Through one mishap or another scores of modern airmen have met a similar fate; yet in spite of this man has, through the gasoline motor, learned to fly thousands of miles, moving at a speed rarely equaled in any other type of vehicle, remaining in the air for long periods and alighting safely.

BALLOON VOYAGES

The balloon was the first vehicle which in modern times carried men into the air, and its use was hailed with extraordinary enthusiasm. Many people believed that the whole problem of air navigation was solved. We know today, of course, that it was not, and that only a first step had been taken. It was more than a century and a quarter ago that a balloon made its first triumphant flight, but until the gasoline engine came into use the balloon remained the sport of the element in which it floated, blown hither and thither by the wind like a skiff without oars or rudder. Yet even to float securely in the air was a great triumph for the time, and the way to do this was shown by the Montgolfier brothers in France, on a June day in 1783.

Hot air rises. The hotter it is the more lifting force it has. The Montgolfiers simply filled a big bag with hot air and let it rise, to the astonishment of an admiring populace. It went up six thousand feet in ten minutes, floated along on the gentle wind for more than a mile, then gently descended, unharmed.

Etienne Montgolfier has left us a description of this first balloon. "The aërostatic machine," he says, "was constructed of cloth lined with paper, fastened together on a network of strings fixed to the cloth. It was spherical; its circumference was 110 feet, and a wooden frame sixteen feet square held it fixed at the bottom. Its contents were about 22,000 cubic feet, and it accordingly displaced a volume of air weighing 1980 pounds. The weight of the gas was nearly half the weight of the air, for it

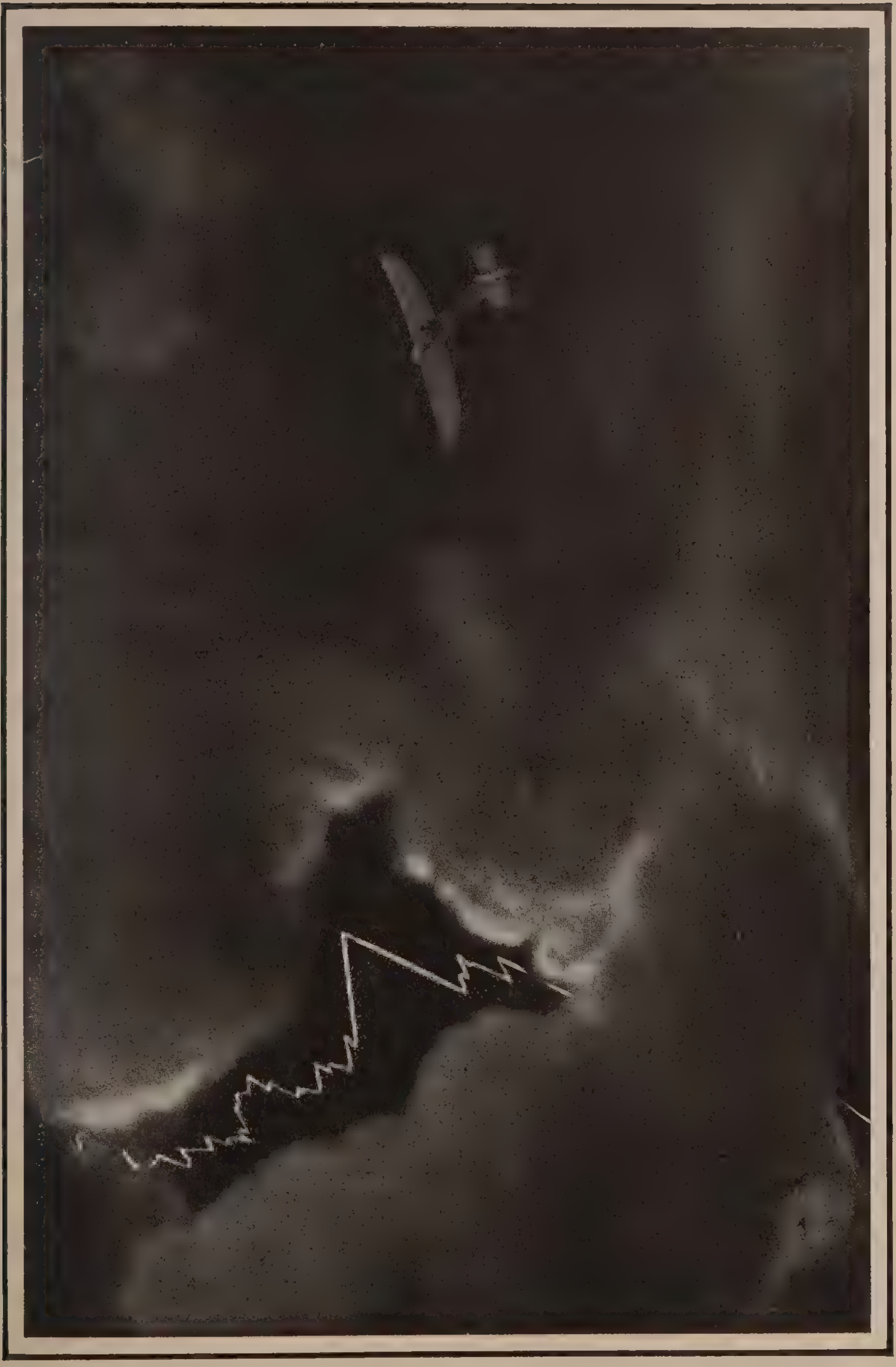
REPAIRING THE GAS BAG OF A BIG BALLOON

weighed 990 pounds, and the machine itself, with the frame, weighed 500 pounds. It was, therefore, impelled upward with the force of 490 pounds. Two men sufficed to raise it and to fill it with gas, but it took eight to hold it down till the signal was given. The different pieces of the covering were fastened together with buttons and buttonholes. It remained ten minutes in the air, but the loss of gas by the buttonholes, and by other imperfections, did not permit it to continue longer. The wind at the moment of the ascent was from the north. The machine came down so lightly that no part of it was broken."

This balloon had neither car nor occupants, but a little later a sheep and some pigeons were sent up and returned to the earth again in safety. Afterward two intrepid Frenchmen went into the air in a captive balloon to the height of several hundred feet and returned to earth unharmed. This paved the way for the first aërial voyage. Roziers and Arlandes were the men who first cut loose from the earth to float in the great ocean of air. They rose three thousand feet in a hot-air balloon, floated across Paris, and descended in safety.

Hydrogen gas, so easily made and so extremely light, had been discovered just a few years before, and this was found to be of great lifting power and lasting. It was commonly used in balloons until illuminating gas came in. This has not so much lifting power, but it is so easily obtained in any city and is so cheap that it is now in universal use in ballooning.

The balloon has been of great use in exploring the upper air. Small ones have been sent to immense heights with recording instruments which have given us knowledge of air pressure, temperature, and other conditions at heights to which man has not yet been able to rise. Large ones, piloted by men, are often sent up now for observation purposes, and with the use of balloons the air currents of the upper air are being studied and a sure foundation laid for the practical navigation of the air which now seems near at hand. Balloon racing has become an international sport in which winning contestants travel thousands of miles in a single



AN AIRSHIP CAUGHT IN THUNDER-CLOUDS — ONE OF THE MOST THRILLING EXPERIENCES OF AN AVIATOR flight. An intimate knowledge of air currents often enables the pilot to choose his direction, but the balloon of to-day is as dependent upon the direction of the wind as were the early ones of the Montgolfier brothers.

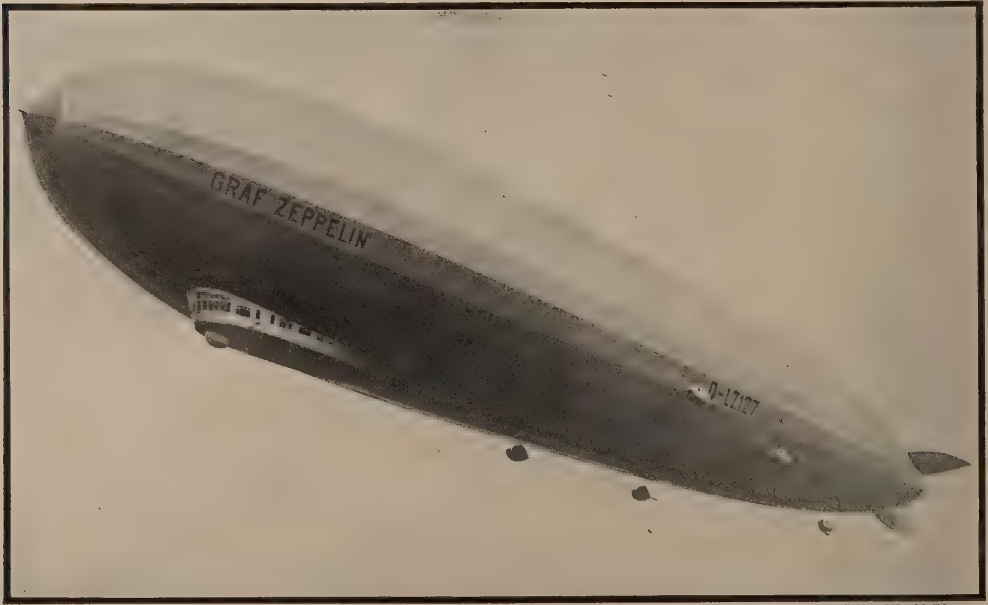
THE DIRIGIBLE

In the dirigible the balloon principle is applied to a long, cigar-shaped or fish-shaped envelope plus a gasoline engine. With this we have a motor-propelled airship capable of making its way against a considerable wind. The idea is certainly as old as is that of the balloon, perhaps older, and it has been almost made practical several times during the last century. Shape, rigidity, rudders, and propellers were all thought out long ago, but the lack of a light, sure engine made all attempts failures. A gentle breeze travels at ten miles an hour, an ordinary wind at from fifteen to twenty. The great inflated envelope is like a huge sail, and an airship, to make any progress in even ordinary weather, must be capable of making about thirty miles an hour.

The first aërial craft to make a journey and return to its starting point was "La France." In 1884 Captains Renard and Krebs of the French army ascended from the military balloon ground at Chalais-Meudon, covered a distance of two and a half miles, and returned at a height of a thousand feet, alighting safely at the point of departure. From that time on the war departments of several European nations, especially France and Germany, vied with one another in producing monster airships whose great lifting power, great engine power, stability, and ease of control made them really wonders of the modern world. In 1898 Santos-Dumont, a brilliant young Brazilian, began building small dirigibles in Paris, in eight years constructing fourteen airships and rousing enthusiasm in regard to air navigation to the highest pitch.

THE AIRSHIP

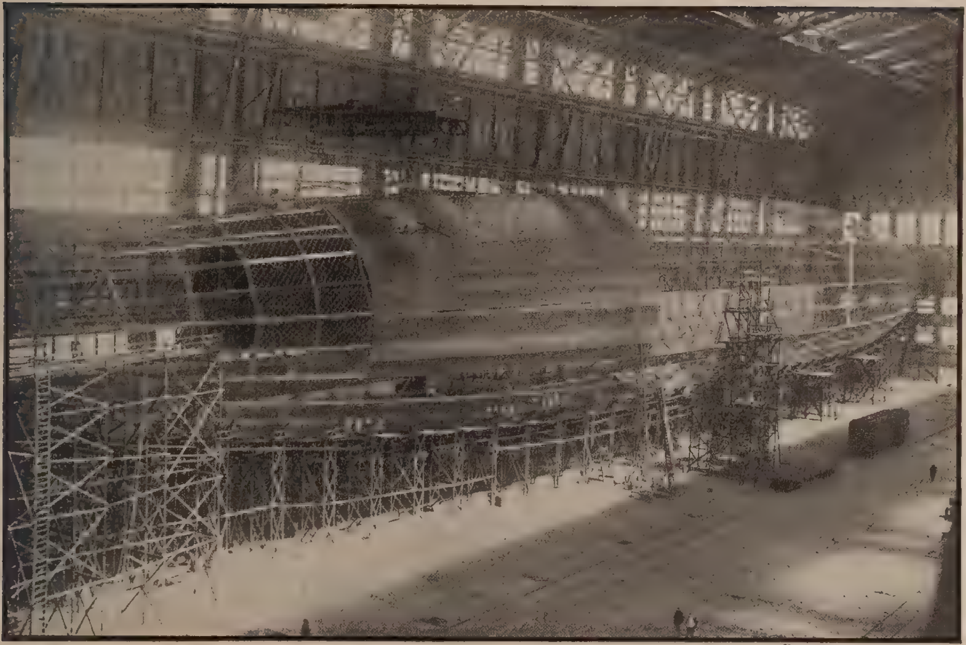
Count Zeppelin of Germany was the most indefatigable airship builder. His enormous dirigibles, Zeppelin I, II, III, were the marvel of their time in size and achievements. Through his efforts, the enthusiasm of the German War



Wide World Photo

THE GRAF ZEPPELIN

First commercial air liner to span the Atlantic Ocean, October, 1928, bringing mail and passengers.



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A DIRIGIBLE UNDER CONSTRUCTION

In this photograph of a navy dirigible the rigid steel framework is shown, partly covered with canvas which will be painted with an aluminum compound to deflect the sun's rays and prevent the heat from expanding the many little balloons filled with helium gas which will be placed within. This airship is 680 feet long, 78 feet in diameter. It will be driven by six engines hung in cars from the framework.

Office, and the backing of the whole German people, Zeppelin's first was begun in 1898 on the lake not far from the town of Friedrichshafen. The envelope was prismatic, with 24 surfaces, 420 feet from end to end, and 38 feet in diameter, coming to a gradual point at each extremity. The framework of the envelope was of aluminum latticework, covered with linen and silk material treated with pegamoid. In each of the seventeen compartments were linen gas bags, together capable of holding some 400,000 cubic feet of hydrogen, leaving an air space between them and the outer covering which would prevent any sudden alterations of temperature and consequent ascending or descending of the vessel. Two cars about twenty-two feet long were rigidly attached below the envelope, less than a quarter of its length from each end, and to give additional strength and rigidity a triangular keel of aluminum latticework was attached below these cars, and from this was suspended a movable weight worked by a winch, enabling the bow of the vessel to be directed up or down. In each car was a sixteen-horse-power motor, driving two four-bladed screw propellers fitted with reversible gears, so that the airship could be driven either ahead or astern. The main vertical rudder was fixed to the stern of the envelope, while for steering purposes and intercommunication the cars were fitted with electric signal bells and telephones.

Although these great ships are unfit for certain war manoeuvers, their size and construction make them available for large crews and heavy loads. The Zeppelin ZR-3, now the U. S. S. *Los Angeles*, was flown here from Germany in 1924 with thirty-two persons on board. The huge *Graf Zeppelin*, 770 feet long, and carrying sixty or more passengers and crew, has already made three round trips across the Atlantic, and has flown around the world as well. An idea of the tremendous size of these ships may be gained by comparing the sizes of the airship framework and the freight car in the picture.

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THE WRIGHT BROTHERS AND THEIR SISTER, MISS KATHARINE WRIGHT

Photograph taken on board the steamer upon the return of the aviators from their triumphant visit to Europe in 1908-1909. Besides winning many important prizes, the Wrights established new records for distance and duration flights and for high flying. In Spain they were received by King Alfonso, who inspected their machine and watched several flights. The king of Italy and the king of England also expressed warm interest in their performance. The admiral of the Italian navy and several officers of the army accompanied Wilbur Wright in exhibition flights near Rome.

REAL FLIGHT

But sailing in the air in a balloon or even motoring through it in a dirigible is not flight. The dream of the early ages, the power to soar through the air on real wings, came true through the inventive genius and daring of the two Wright brothers, Orville and Wilbur, who began to try their wings at Dayton, Ohio, who later found freedom from crowds among the sand dunes of North Carolina, and who finally flew in the first real flying machine that the world ever saw.

Before that many men, notably Lilienthal, Chanute, and Pilcher, had found it possible to glide through the air on planes which were something like wings. They learned to run toward the wind, launch themselves in the air from the top of a hill, and sail down to earth at a considerable distance. They thus found out in a rough way how to manage wings, or more properly planes. The Wrights began in the same way, and after they had mastered the "glider" they added a light engine, a propeller, and a rudder in front and in the rear by which to steer. They learned to prevent their machine from tipping sidewise by warping the wing tips, and they had the first practical flying machine.

This was the biplane, and the type has been found ever since to have great stability — that is, not to be easily tipped over — and to have great lifting power, though the machine is not so swift as the monoplane.

THE STORY OF THE WRIGHT BROTHERS

In all history the names of the Wright brothers will go down as the inventors of the first real flying machine. It was in 1900, the first year of the twentieth century, that these two young men began the work which was to make them famous.

At their bicycle shop in Dayton they made gliders after the plans of Lilienthal, Pilcher, and Chanute, and did their best to learn to fly with them. Chanute, who was in Chicago at the time, was able to give them much good

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THE WRIGHT MOTORLESS GLIDER

Orville Wright trying out the new glider at the Kill Devil hills. In perfecting this machine the Wrights achieved one of their first great successes.

advice out of his long experience, but they found in their home town little but ridicule and unbelief. To make a flying machine was in the minds of many as bad as to attempt to invent perpetual motion. The ridicule and skepticism to which they were subject is but the penalty which all people who are in advance of their age have to undergo, but it was not pleasant and it made their work more difficult. As they needed secrecy and a better field for trying out their experiments, they went down into a wild part of North Carolina. Among the Kill Devil hills they found sandy stretches of barren country where they were secure from all interruption.

There they worked patiently, building carefully with such tools as they possessed, trying out each new device with scrupulous care, methodical, patient, hard-working young inventors in whose lexicon there could be no such word as "fail." It was in 1900 that they began, and so slow and careful was their progress that it was not until two years later that they succeeded in making a glide of three hundred yards. In doing this they had brought the glider to a pitch of mechanical perfection and stability never before reached. But they had done more than this. Each had become far more skilled in the management of the machine, the instinctive balance and automatic foresight necessary for successful flight, than any other man who had attempted flight with a heavier-than-air machine. Out in the wilds of the Carolina hills the Wrights had the best gliding machine which the world had yet seen, and were themselves masters of the air, having that instinctive feeling for safety in flying which the bird has and which is one of the most important traits of the bird man.

THE FIRST MOTOR-DRIVEN MACHINE

The next year was to see a great advance in their experiments. They fitted a little motor engine and a propeller to their glider, and began to learn the game all over again with the same methodical persistency that they had always displayed. Here was a whole series of new problems to be solved, and each must be solved under penalty of probable death. In the invention and improvement of most machines a failure means simply vexation and more work.

But a failure in the placing of their engine and the construction and operation of their propellers meant grave danger for the daring inventor who should try to fly with the new appliances. The brothers went at this work as keenly and methodically as they had attacked the gliding problems, and they succeeded in the same way. But they worked two years more in such seclusion as they could command, striving steadily to perfect their invention before the world should find them out. And in a large measure they succeeded. In 1905 the startling fact was published that these two unknown inventors, working in secrecy in the Carolina hills, had made a flight of twenty-four and a half miles. Up to that time occasional reports had been printed that they had made successful flights, but the public were slow to believe this. The lack of confidence which the inventors had experienced in Dayton was for a time their portion in the wider world. But this did not trouble the Wrights. They were as serene through all this as they were later when no praise was too great for their astonishing feats—types of that modest, self-reliant American manhood which has always been deemed worthy of the highest praise. The Wrights have since that time made great advances in biplane construction, but it should be said that, down in the wilderness of the Kill Devil hills, with only the simplest appliances and tools, they brought the original machine to a high pitch of mechanical perfection.

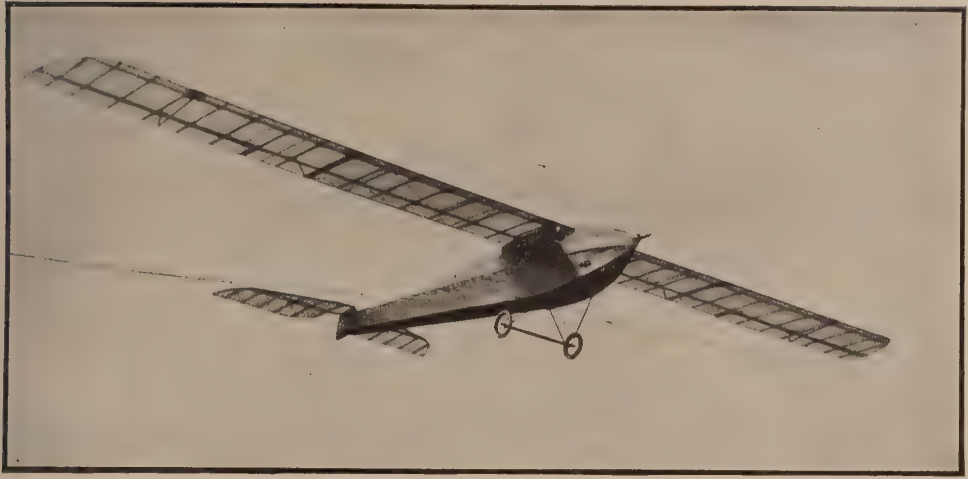
WINNING THE FIRST PRIZE

It was in 1905 that the tide of popular approval turned in favor of the Wright brothers. For a time no one had seemed to believe in them. Now the world was all agog with prophecies of

Wide World Photo

IT FLOATS ON THE WATER, FLIES IN THE AIR, AND TAXIS ON THE LAND

This plane, with its luxurious cabin accommodation, attains a speed of over 100 miles an hour, with a single "whirlwind" engine.



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A GLIDER

Other aëroplanes depend for motive power on their engines. The glider, which is one of the newer inventions, depends on and takes advantage of the currents of the air, floating as a kite floats, but directed and controlled by its pilot. This is the De Haviland glider, making one of its first flights. While the glider is still in a sense the toy of aviation, no one who reads of the first flights of the Wright brothers and compares them with the present transcontinental flights can fail to recognize that in every experimental type of machine there may be some new discovery which will greatly improve the airplane of the future.

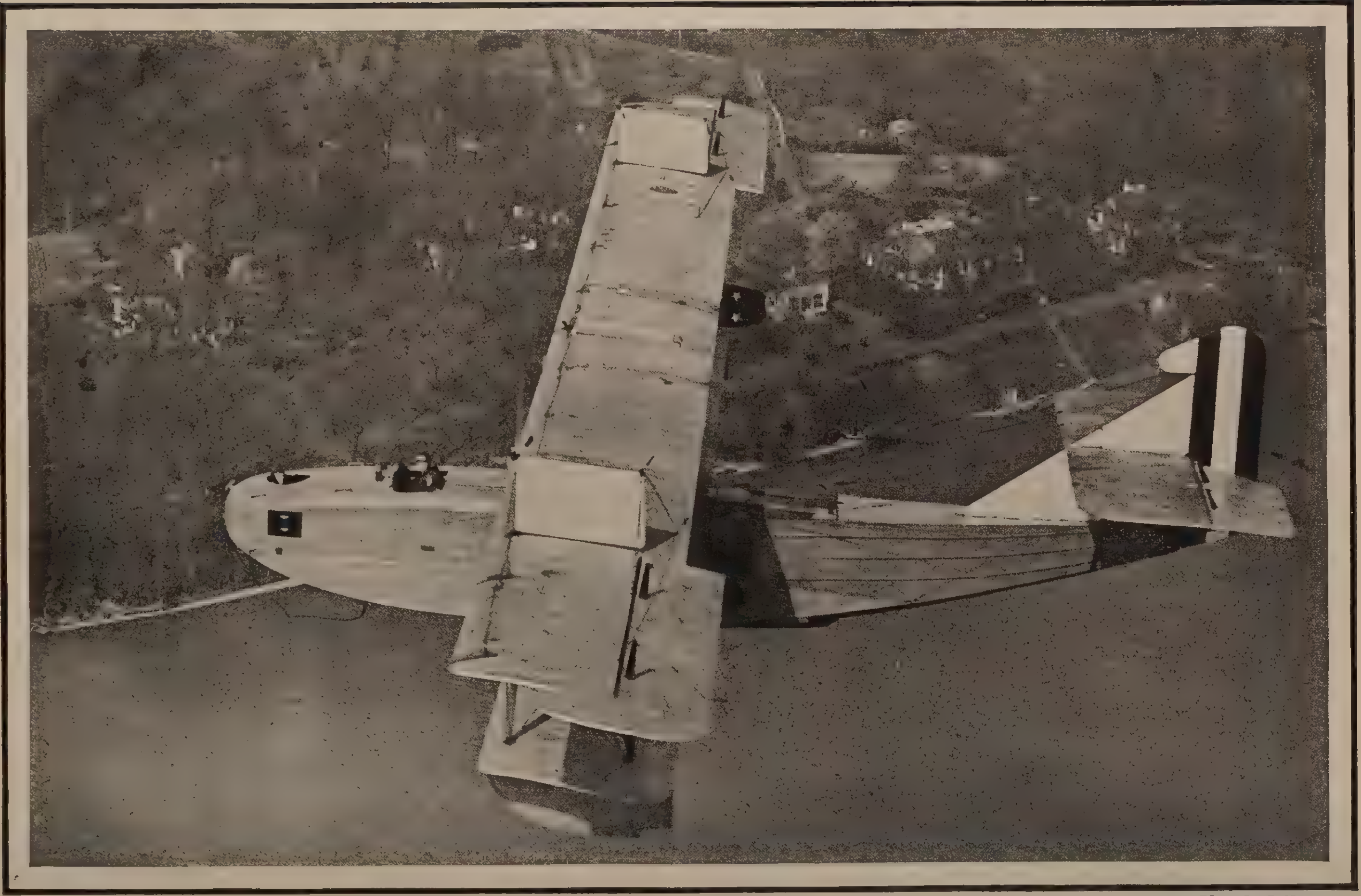
the great things which were to come from aviation. In most civilized countries inventors were experimenting with flying machines, and the Wrights were obliged to stop flying and experimenting on flying machines to attend to business negotiations in regard to the use of their patent rights. Thus time passed swiftly by, and it was almost three years later, in the spring of 1908, that they began tests again. They had improved and increased the power of their motor and had agreed to furnish a machine for the United States Signal Corps and one to a French syndicate.

The machine which was to be furnished for the Signal Corps must be able to carry two men and to fly for one hour without stopping at an average speed of forty miles per hour. This flight must be made across a rough country, dotted with hills and valleys, forest and open field. Another requirement was that the machine should prove that it could go 125 miles without stopping. The Wright brothers agreed to furnish such a machine for $25,000, and Orville Wright went to Fort Myer, Va., near Washington, to complete the test under the conditions as specified by the government.

IN THE AIR FOR AN HOUR AND THREE MINUTES

The world, once disbelieving, was now wildly enthusiastic. Thousands flocked into the drill-ground to see this first public appearance of the noted young inventors and their marvelous machine. The preliminary flights were successful in all particulars, and in the final test Orville Wright flew the machine an hour and three minutes. Later, for the first time in America, he took a passenger in the air. Lieutenants Lahm and Selfridge were each thus favored with short flights.

The triumph of the Wright brothers was great and well deserved. The newspapers the world over devoted pages of space to the men, their machines, and the wonderful new power thus given to mankind, the dream of the ages being fulfilled at last in actual flight. Somewhat later the world was shocked by the first fatal aëroplane accident in America. Orville Wright was in France, exhibiting a machine at Le Mans; Wilbur Wright at Fort Myer continued to make ascents. One day he was about seventy-five feet in the air with Lieutenant Selfridge



Official Photo, U. S. Navy

NAVY PATROL AND SCOUTING PLANE

Scouting at sea has developed into an important function of naval aircraft and requires planes possessing long endurance. This twin-engined type has two Liberty engines of 400 horsepower.

3
Ford
DETROIT—CLEVELAND

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AT A COMMERCIAL AIRPORT

One set of passengers arriving, another group departing, at a transcontinental "station." Each plane carries six passengers, besides freight and mail.

when one of the stay wires on his machine broke, wrapped around the propeller, and the machine, no longer under control, plunged to the ground. Lieutenant Selfridge was killed and Orville Wright had several bones broken. The machine had, however, before this accident completely fulfilled all tests, and the United States was the first nation officially to adopt an aëroplane for military purposes.

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THE WRIGHT AËROPLANE IN FLIGHT

This photograph was taken less than one minute before the accident occurred.

THE WORLD AVIATION MAD

Soon the world began to go aviation mad. The new science fascinated participants and observers alike. Inventors in every land were at work on all sorts of machines, and aviation meets began to be held everywhere, in which daring acrobats of the air showed marvelous skill in the management of the new machines. Crowds of scores of thousands watched competition in flight over measured courses with keen delight in the racing, large sums of money were offered for prizes to the aviator rising to the greatest height or making the longest cross-country trip, and in countless other ways the new sport was encouraged. In many of the most important of these meets the Wrights took part, being often victors.

Everywhere schools of aviation were started, and the number of aviators began to be legion. Besides the Wrights, great names of the day in aviation were Curtiss, Blériot, Farman, Latham, Paulhan, and many others who took part in the first great international meet at Rheims. There Curtiss won the speed prize in a sixty-horse-power biplane of his own make, in two rounds of the field at a rate of 47.04 miles per hour. This speed was acclaimed at the time as wonderful, though now, but a few years after, military speed records make these early achievements interesting only by contrast. The first altitude prize at an early meet was won by Wilbur Wright, with a record of less than 400 feet, though now aviators have climbed to an indefinite height. At the first Rheims meet the distance prize, the "Grand Prix de la Champagne" of $10,000, was won by Farman, flying patiently in his slow biplane 68 miles.

So the record of increased power and stability in the machines increased almost daily, as well as the skill evinced by aviators. Great credit is due to many inventors — Curtiss, Langley, Herring, Bell, Baldwin, McCurdy — and particularly the Wrights in this country, while abroad a great host of inventors and experimenters have aided in planning and perfecting scores of varieties of machines. One cannot attempt to name them all. Santos-Dumont was a pioneer in flight by means of the aëroplane, just as he had been a pioneer in the use of dirigibles. Indeed, authorities agree that his was the first free flight of a power-controlled flier ever publicly seen in Europe. Two years before that a man by the name of Ader is said to have flown a machine in secret, but the flight of Santos-

Official Photo, U. S. Navy

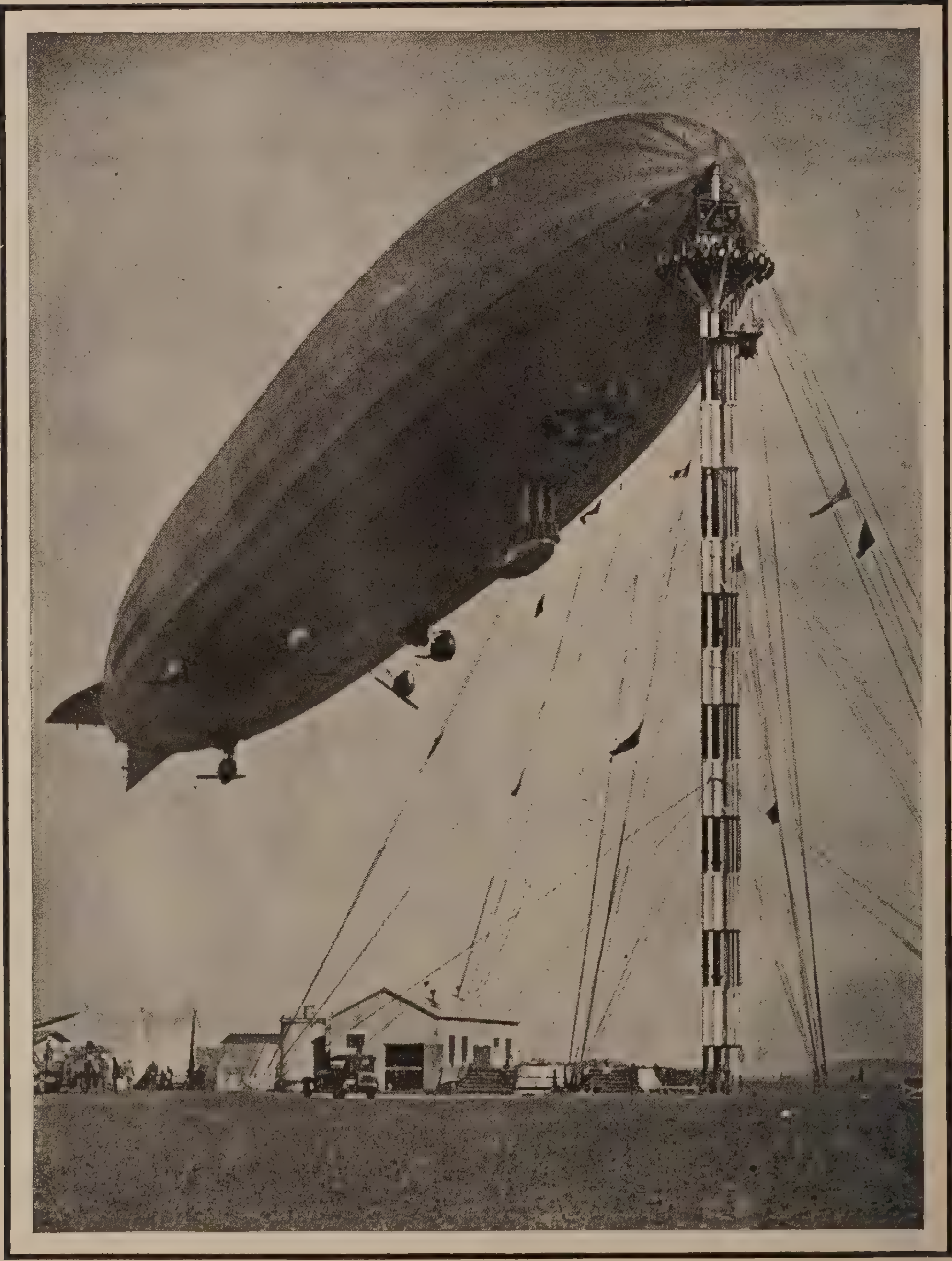
A SEAPLANE RACER, CAPABLE OF GREAT SPEED

Dumont was made before several thousand people. Two months later, in October, 1906, he made a flight of 221 meters in 21 seconds, winning the Archdeacon Cup of two thousand francs authorized by the Aëro Club of France for a flight of 100 meters. This was a year after the Wrights had made their flights alone in the Carolina wilderness.

In 1907 the Voisin brothers finished a biplane in which Henri Farman and Leon Delagrange astonished the world. Then Blériot succeeded in flight with his monoplane, which has ever since remained a splendid type of swift flier. Blériot made failure after failure in his attempts to build a successful machine from 1900 until 1908, but in October of the latter year he made a cross-country flight of seventeen miles, the second ever attempted, Farman in his biplane having done about the same distance the day before. Blériot was the first man to cross any long stretch of open sea, his cross-channel flight giving him world-wide fame.

CROSSING THE ENGLISH CHANNEL

The London *Daily Mail* offered a prize of five thousand dollars for the first aviator to cross the English Channel. The French aviator Latham narrowly missed winning this prize, but fell in mid-channel, being rescued with his machine by an attendant tug. Then Blériot tried it. The plucky aviator had been severely burned by



Official Photo, U. S. Navy

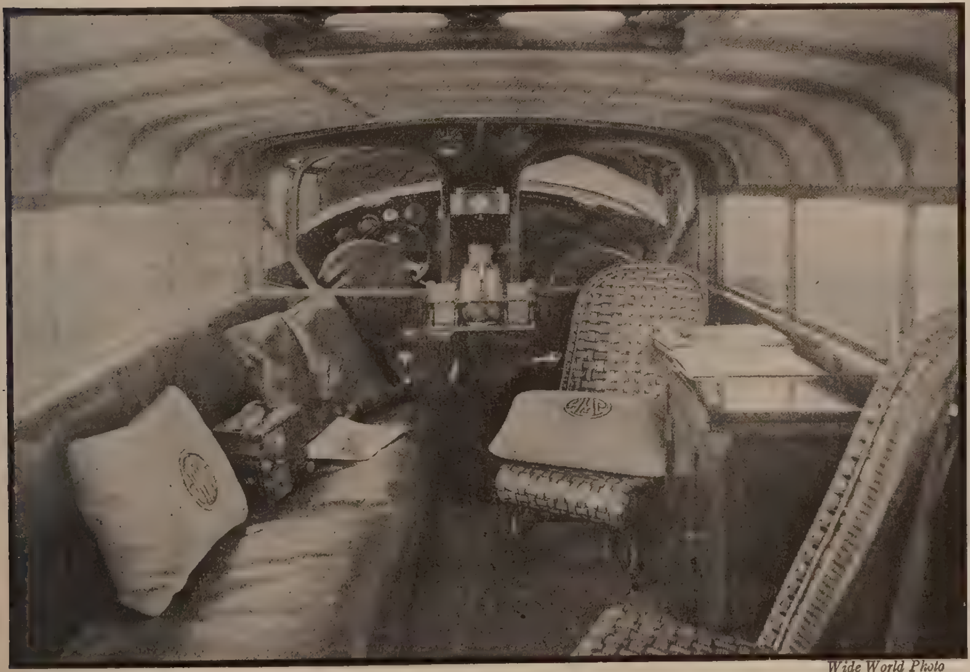
SHENANDOAH AT MOORING MAST

The Shenandoah, pioneer American rigid airship, was built in this country under the direction of the U. S. Navy, and placed in commission October 10, 1923. The ship made many successful flights until on September 3, 1925, it was caught in a severe Mid-Western tornado and broken in two with a loss of life of fourteen men.

a gasoline explosion just a few days before and could barely hobble on crutches. Nevertheless, he bade his attendants lift him into the machine. "I'll show them that I can fly if I cannot walk," he said, and in a few moments he was sailing through the air over the Channel at a rate that soon left the swiftest attendant torpedo boats behind. The day was fair and the wind gentle. The intrepid airman was out of sight of both coasts for a matter of perhaps ten minutes, sailing the chartless air over the trackless ocean. Then the white chalk cliffs of Dover appeared, and soon afterward he alighted safely on English soil. It was the great aviation feat of his day, and his success was flashed round the world by telegraph and cable, and was acclaimed in all lands.

This was in the summer ot 1909. Since then feats have been accomplished in aviation before which this seems the veriest commonplace. Chauvez sailed from France to Italy over the Alps. The American continent was crossed, and even before the war European aviators made little of traversing distances of four or five hundred miles in a single flight at speeds of from 60 to 150 miles an hour. The effect of the war was to make what was an unusual exploit of an individual aviator with an experimental machine the everyday performance of thousands of men using standardized machines of high perfection.

With the military service of the airplane all readers of current newspaper and magazine reports are more or less familiar. Increased strength of construction and additional equipment for control have made the machines safer, while the improvement in motors has been rapid. As over against the 80 to 110 horsepower engine of "before-the-war" days we read of motors developing 400, 500, and 600 horsepower. The close interdependence of the airman and his engine-maker is one of the interesting and significant facts in the evolution of flight. The Wright brothers in 1903 had

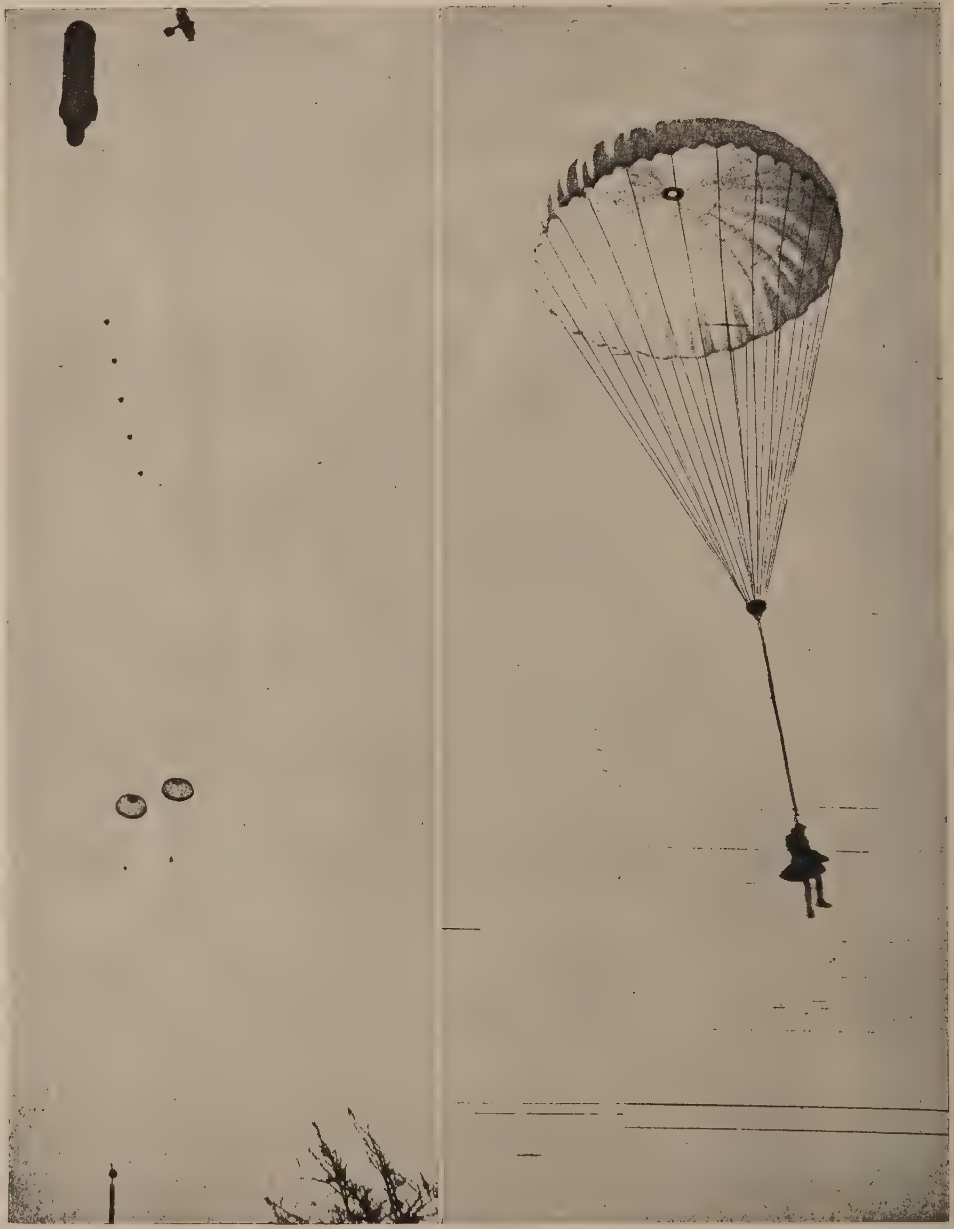


Wide World Photo

LUXURY IN AIR TRAVEL

The cabin of this air yacht is commodious and comfortable.

A MIRACULOUS ESCAPE BY PARACHUTE



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AN OBSERVATION BALLOON ATTACKED

The enemy airplane has set fire to the balloon, which is falling. The observers have escaped, each in his parachute, and are descending to safety. At the left is the whole scene, at the right a closer view of the descending parachute.

made an engine weighing 152 pounds and delivering 12 horsepower, or 1 horsepower to every 12⅔ pounds of weight. At that point it was possible for man to fly. Five years later they had evolved an engine that would deliver a horsepower for every 5½ pounds of weight. Many airplane engines now deliver a horsepower for about 1¾ pounds of weight. On the relation of the engine to the machine depends in large measure the possibility of rapid climbing, swift manoeuvering, long flights, and the ability to do the "stunts" which, however reckless they appear, are often the only means of attack, defence, and escape of the fighting airman.

"Before the war," says E. B. Wilson, "there was much criticism of professional exhibiting aviators, who, to thrill spectators, put their machines into all sorts of daredevil attitudes and frequently themselves came suddenly down to death. In fighting, the ability to do all manner of 'stunts' is essential. The more completely a pilot can control his machine, the more easily he can toss it hither and thither — cutting figure-eights, looping the loop, nose diving, and tail diving — the better chance he has for his own life and the more certain he is to get his opponent."

British statistics show that during three years, when many thousands of men were being taught to fly, there was one death in each 125,000 miles of flying, a surprisingly small casualty record in a new science taught at a forced rate of speed.

THE UNITED STATES IN AVIATION

The entry of the United States into the war found us far behind the European nations in the design and construction of aircraft. To supply the needs of our army and of the allied forces, it was found necessary to start immediately on the building of twenty thousand airplanes. So boldly did our manufacturers attack this problem that in eighteen months of almost superhuman effort fifteen thousand completed airplanes were delivered. Need for an engine that could be made in quantities was met by the development of the Liberty motor, twenty-four thousand of which were produced in the same period of time.

With the close of the war, the aviation industry in this country collapsed completely. Little interest was shown in aircraft, and only a few of the stronger manufacturers were able to struggle along in anticipation of a brighter future. In Europe, the various governments were using their resources for the promotion of commercial aviation and the encouragement of aeronautical science.

Rear Admiral Byrd's flight across the North Pole in 1925 was the first of a series of stirring events that re-awakened public interest in aviation. The climax was reached in Colonel Lindbergh's thrilling non-stop flight from New York to Paris in 1927. This was the event that brought to the world, in dramatic fashion, a full realization of the possibilities of the airplane as a new and important means of transportation.

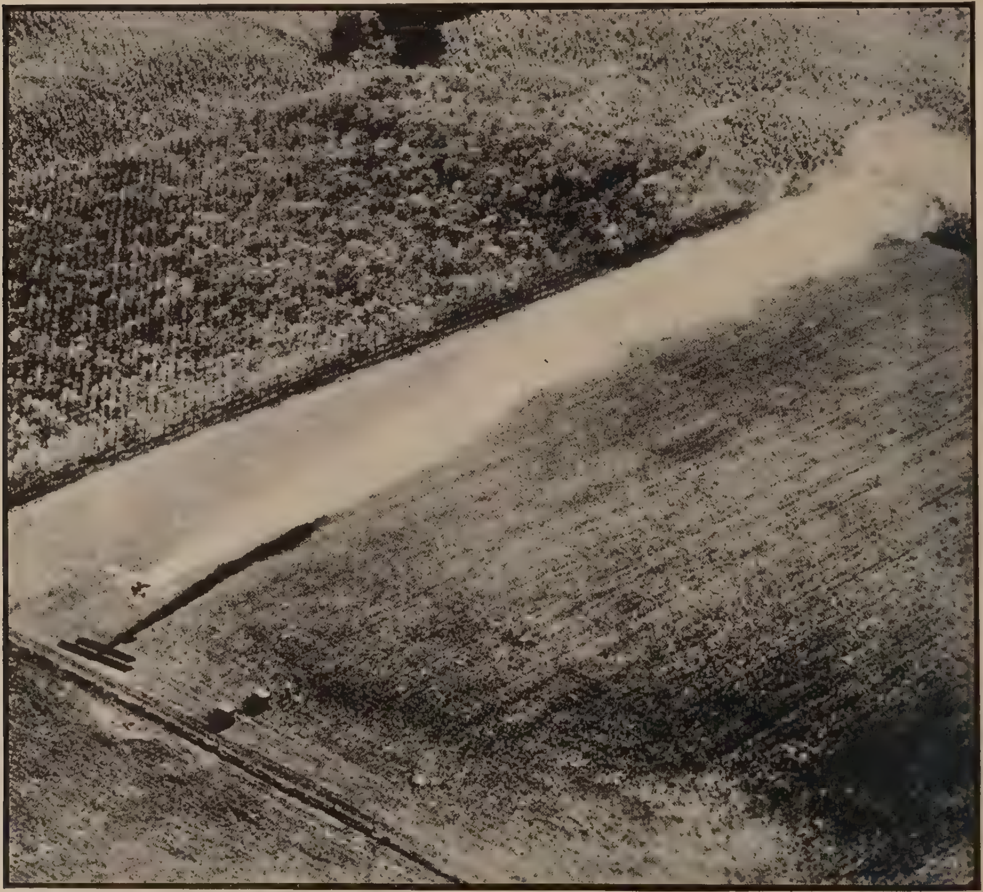
A prophetic view of the effects of aviation on a peace-time world is found in a quotation from Rear Admiral Robert E. Peary, discoverer of the North Pole. He said, "Utilization of the atmosphere for commerce and transportation presents possibilities far beyond anything we can imagine. Sea power — military and commercial — has been for centuries an absolute essential to every great nation. . . . We are now entering on an era of air power . . . which in the future will be as far superior to the greatest sea power as the unlimited ocean of atmosphere now sweeping unbroken about the globe is greater than the land-bordered Atlantic or Pacific."

Hundreds of thoroughly trained pilots are today engaged in flying as a profession. They "fly" the air mail; operate great passenger and express planes; engage in aerial photography and surveying; patrol the coasts, and guard crops and forests.

Business organizations and newspapers own private planes for rapid transportation on important errands. Even whaling vessels and the fishing fleets call on the airplane for aid in locating prospective catches.

Already an airplane has been perfected and flown which has twelve motors, three decks, and accommodations for one hundred people; airplane passenger and mail lines link continent to continent; exploration of unmapped portions of the earth is under way; and our own continent is crisscrossed with airways and dotted with airports.

Aviation has moved forward by such leaps and bounds in the last ten or twenty years that it is hardly safe to record any figures or to give any but general statements. Still, remembering those early flights at the first International Meet at Rheims when in 1909 a first prize was won by Curtiss for flying twelve miles at the rate of forty-six miles an hour and when the altitude record was four hundred and ninety feet, we should stop a moment to marvel at to-day's airplanes with a speed which approaches a rate of five miles a minute and an altitude record of a little more than seven miles. In both cases it would seem as if the limitation were a human one. Certainly it has so proved in the case of altitude, as aviators cannot keep sane and conscious at the greatest heights to which they can pilot their craft.



Photo, Bureau of Entomology

AIRPLANE DUSTING COTTON FIELD FOR BOLL WEEVIL DESTRUCTION

THE AIRPLANE IN PEACE

While tests are constantly going on which keep before our minds the development of the airplane and the airship for war purposes, the interest of the world is turning strongly to the practical uses of these machines in the daily life of the nation. The Government has found many uses for the airplane. Chief of these is the Air Mail, of which pictures are shown in

Volume Ten, page 277. Started in connection with the World War, it is operated by the Post Office Department in conjunction with private flying companies, and has a wonderful record of service to its credit. It carries mail from New York to San Francisco in thirty-four hours, and from San Francisco to New York in thirty-two, with service on other routes touching most of the larger cities. In spite of all its hazards, it outclasses in regularity any air-mail service in the world and should be the pride of every American. Its range is fast being extended to include other cities, and the chain of landing fields and beacon lights which mark its pathways is lengthening from month to month.

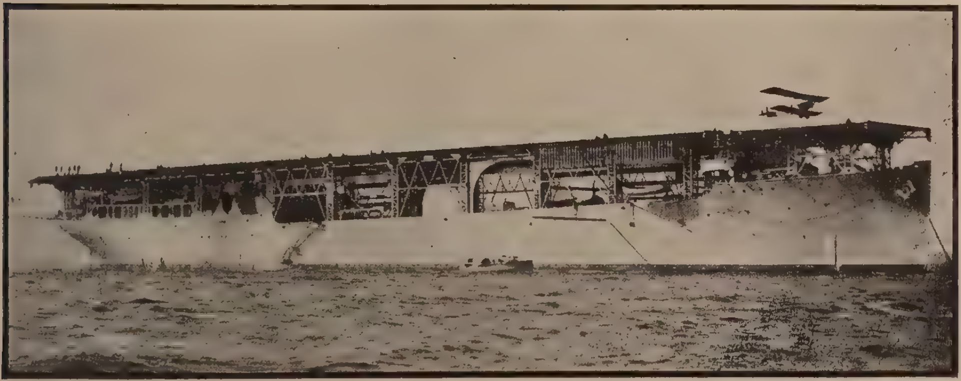
Commercial aviation has for years been an established fact in England, Europe and the Mediterranean countries. Nearly all the larger cities of Europe are now on established passenger air lines, which cover their routes with great speed and regularity at fares little more than those charged on the slower trains. While our own commercial service was later in starting, it has grown at such a tremendous rate that we now have more miles of passenger and express lines than any other country. A transcontinental service operated by the railroads now makes it possible to go from New York to San Francisco in about two days, flying during the daylight hours and transferring at night to railroad sleeping cars. Other companies maintain lines between important cities, while another connects this country with South America.

IN PUBLIC AND PRIVATE USE

The airplane has proved of great service both to the Government and to private companies in combination with the aërial camera. By its means it is possible to make in the space of an hour or two a photographic survey of excellent accuracy either of a city or a swampy region or a mountain pass which it would take not only time but the risk of personal danger to accomplish by other means. Crop estimates can also be made by photographing large acreages in several successive years.

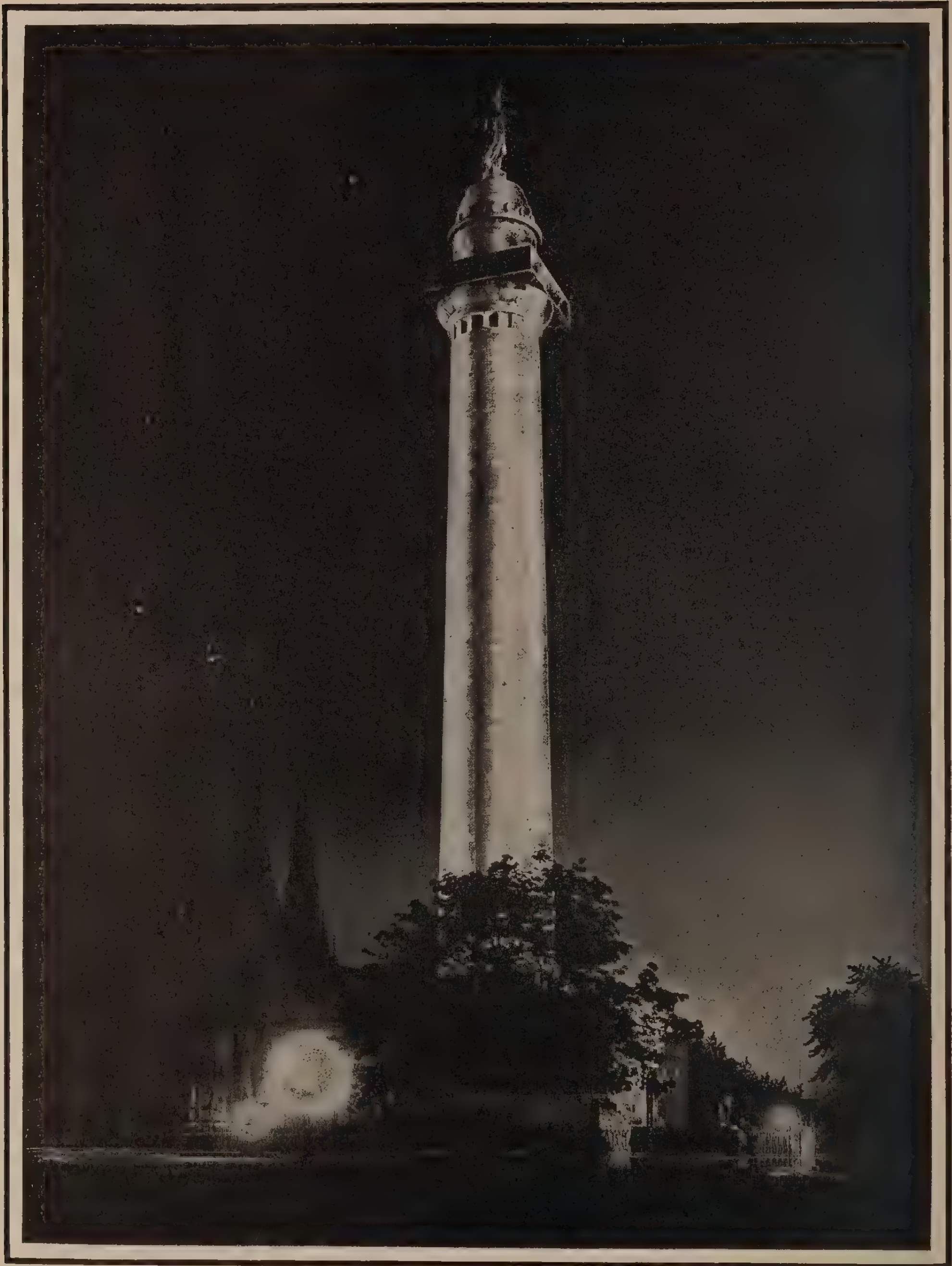
A similar use is that of scouting for forest fires, which can be quickly located and reported by the hovering machine. Here the airplane combines with the radio to wipe out the former difficulties and dangers of isolation. In the warfare on insect pests it has proved practicable to dust the cotton fields from above with a substance unwelcome to the boll weevil and to spray swampy grounds to prevent the breeding of malarial mosquitoes.

The story of aviation, both in the airplane with its service for shorter distances and in the airship with its gains for long non-stop flights, is written in our daily papers and current periodicals. Civilization has always marched hand in hand with transportation. Man to-day has a vehicle swifter than any which was ever before devised and moving in a new medium, the air. It remains to be seen how it will affect the life of man in the next twenty-five years.



Official Photo, U. S. Navy

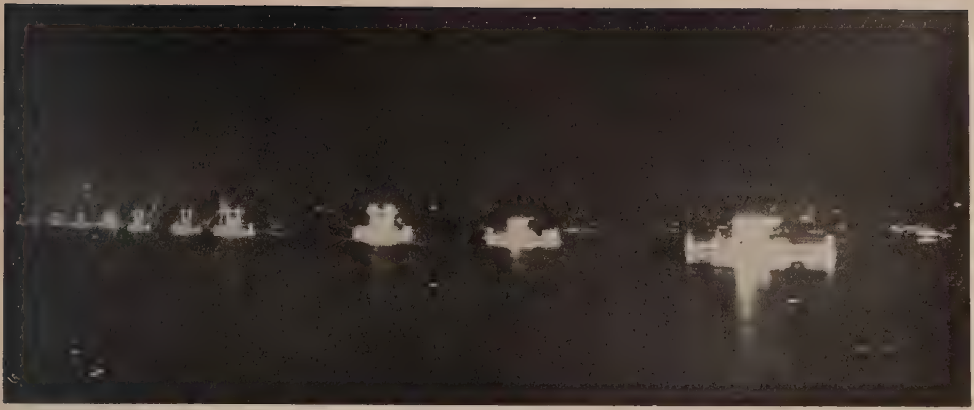
AIRCRAFT CARRIER WITH A PLANE TAKING TO THE AIR FROM THE FLYING DECK



Photograph by A. Jackson Co.

WASHINGTON MONUMENT, BALTIMORE, AT NIGHT

One of the grandest monuments in the world. The design was furnished by Robert Mills, while the noble figure of Washington is by Causici. The style is of Greek Doric inspiration. The monument is here shown illuminated by a searchlight turned upon it from an adjacent building.



A FLEET OF BATTLESHIPS ILLUMINATED BY ELECTRIC LIGHT

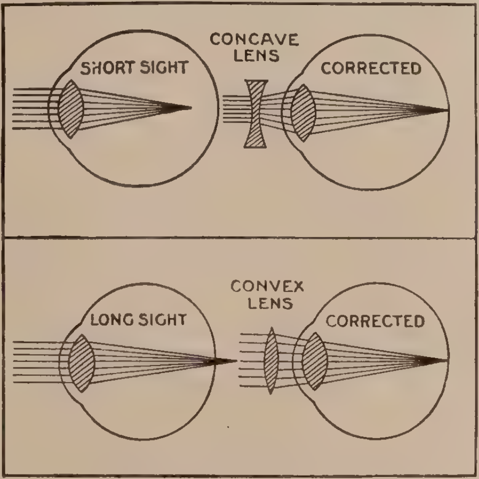
THE MIRACLE OF LIGHT

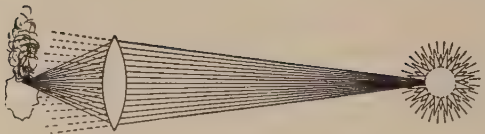
ONE of the great miracles of existence is light. Scientifically speaking, light consists of vibrations in the ether which fills all space. The sun, which is the great source of our light, sends it to the earth at the rate of 186,000 miles in a single second. Only the lowest forms of life can get on without light, and without direct sunlight the higher forms fade and die. It is one of three great wonder workers which may have the same source and of which the other two are heat and electricity. Chief among the marvels produced by light is the adaptation of animal and plant life to receive it and benefit by it. Of these adjustments none are more wonderful than those made by that delicate mechanism, the human eye.

THE MARVEL OF THE HUMAN EYE

The eye is a wonderfully adaptable hollow ball, with a window in the front and the hollow filled with a transparent liquid. It also contains a focusing screen by means of which the sight is adapted to things near or far, as the will of the brain behind the eye may direct. A special nerve carries the image which comes through the lens to the brain, and thus the person sees. It is quite like the working of a splendid self-adjusting camera, the picture remaining for a little space of time on the brain after the lens ceases to produce it.

But sometimes the round lens of the eye is not of quite the right shape for perfect vision. It may be too spherical, and then the person cannot see things at a distance well. The lens is out of focus there. It may be too flat, giving splendid vision at great distances but blurring things, out of focus again, near to. So, long ago, people who made things of glass found that a glass lens could be put before the eye that would correct these misfortunes in eyesight. Above are some diagrams of the





A BURNING GLASS CONCENTRATING THE HEAT RAYS WHICH FALL UPON IT

eye and its lens and the glass lens in front of it, showing how the glass catches the parallel rays of light and makes them focus just right on the retina of the eye, which is the screen whence the nerve takes the picture to the brain. Thus eyeglasses or spectacles were invented, and they have been a great boon to mankind ever since.

The common burning glass shows well how the heat as well as the light rays from the sun are focused. If you hold this at just the right distance away from a piece of paper, it will set it afire, but if you hold it too near or too far, so that the paper is not in focus, nothing happens.

THE MICROSCOPE

The burning glass may be used as a reading glass, for if held at just the right place above a printed page, it makes the letters all look much larger, and in this we have the first principle of the microscope. By an arrangement of many lenses in a suitable frame we can thus magnify objects almost indefinitely, and things which are far too small to be seen at all by the ordinary eye are enlarged hundreds or even thousands of times and can be plainly seen and studied. By the use of the microscope scientists have conferred great benefits upon mankind. They have found and studied the exceedingly small germs of various diseases and learned how to destroy them, thus saving people from dangerous and deadly diseases which were once almost always fatal. In this one thing alone the value of the microscope to human life is incomputable.

SIMPLE LENSES

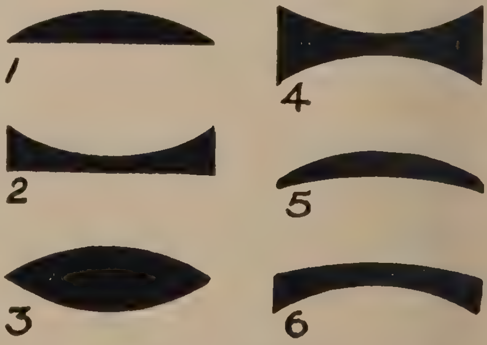
In the illustration are shown six forms of simple lenses such as are used in spectacles and in microscopes, telescopes, and cameras.

Nos. 1 and 2 have one flat and one spherical surface. Nos. 3, 4, 5, and 6 have two spherical surfaces. When a lens is thicker at the middle than at the sides, it is called a "convex" lens; when thinner, a "concave" lens. The names of the various shapes are as follows: No. 1, plano-convex; No. 2, plano-concave; No. 3, double convex; No. 4, double concave; No. 5, meniscus; No. 6, concavo-convex. The thick-center lenses, as we may term them (Nos. 1, 3, 5), *concentrate* a pencil of rays passing through them; while the thin-center lenses (Nos. 2, 4, 6) *scatter* the rays.

GLASSES THAT SHOW US WORLDS

Galileo invented the telescope in 1609. He found that by putting lenses of a certain kind in a tube and moving them nearer together or farther apart he could get things at a distance in focus and see them very clearly and apparently magnified. Opera glasses, so commonly used to-day, are built on the Galilean principle. Galileo has the credit for this invention, for he made the best telescope of his time and with it made important discoveries in astronomy; but the idea was not new at the time, nor indeed was he the only man of his day to make a telescope. Other men during that same year of 1609 were at work on telescopes exactly like Galileo's, among them being Lippershey, Janssen, and Messier. However, Galileo made the best and made the best use of it, so he fairly deserves the credit. No one knows who first got the idea. Roger Bacon wrote about it in 1250, more than three hundred and fifty years before Galileo's day.

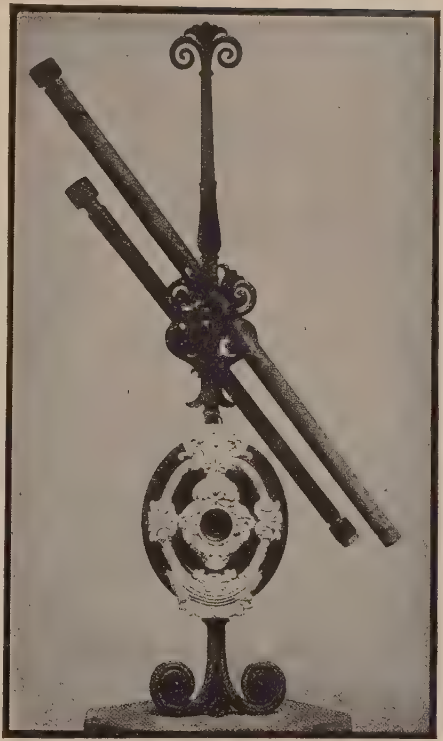
A hundred years after Galileo, Sir Isaac Newton made a reflecting telescope, an instrument



FORMS OF SIMPLE LENSES

containing a mirror as well as lenses, which was a great improvement on that of the original inventor, and since then men the world over have been making bigger and more perfect telescopes, until now we have the great ones at Paris, at the Lick Observatory in California, and at the Yerkes Observatory near Chicago. Galileo's telescope magnified three times, and he made many discoveries with it that were wonderful for his day. It was the size of the ordinary spyglass which one holds in one's hands. The Lick refractor has an object glass thirty-six inches in diameter, the one at the Yerkes Observatory is forty inches in diameter, while the Paris reflector telescope has a diameter of fifty-nine inches and is mounted in a tube one hundred and eighty feet long. With small telescopes it is customary to mount the tube in such a way that it can be moved to point at any part of the sky desired, but it would be impossible to move a telescope the size of the great one at Paris, which is accordingly fixed at a horizontal position. A great mirror which can be readily turned catches the portion of the sky desired and reflects it into the tube. The mirror and its frame are called a "siderostat"; this moves by clockwork, keeping the desired object always in exact focus. This greatest telescope was first used at the Paris exposition of 1878, where, at the eyepiece end, a great amphitheater was constructed in which the public watched stellar and lunar images thrown on a screen thirty feet high while a lecturer explained them. Thus far had the world of invention in optics moved since Galileo's day.

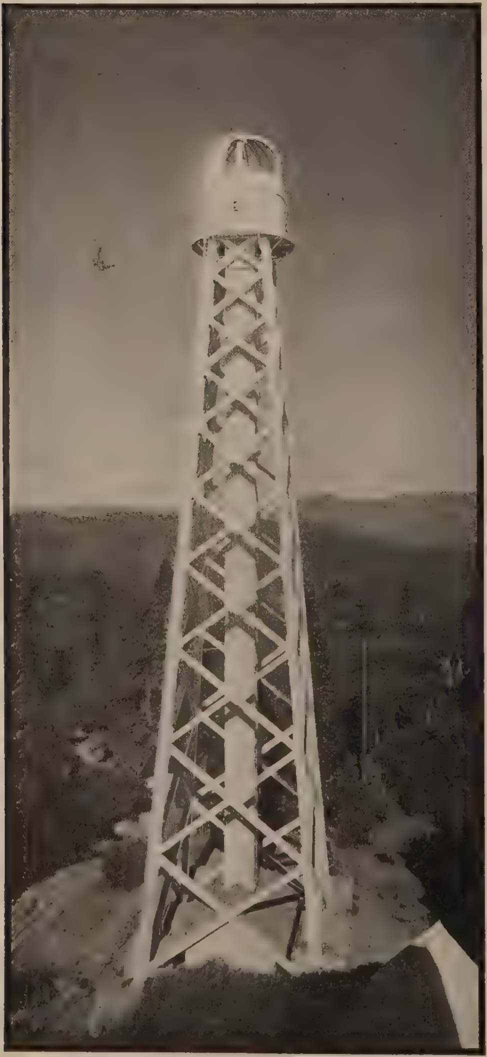
Our own century has seen the erection at the Mount Wilson Observatory, Pasadena, California, of the one-hundred-inch reflector shown in photograph on page 157. Dr. George Ellery Hale, Director of the Observatory, tells in terms which the layman can understand the advantage of this larger instrument. "The unaided eye, with an available area of one-twentieth of a square inch, permits us to see stars of the sixth magnitude. Herschel's eighteen-inch reflector, with an area five thousand times as great, rendered visible stars of the fifteenth magnitude. The sixty-inch reflector, with an area 57,600 times that of the eye, reveals stars of the eighteenth magnitude. . . . Every gain of a magnitude means a great gain in the number of stars rendered visible." Hence the interest in this telescope which will literally enable astronomers to look into worlds hitherto unobserved by the human eye. With this wonderful observatory, which is a branch of the Carnegie Institution at Washington, our skilled American astronomers may well make new contributions to human knowledge.



GALILEO'S TELESCOPE

THE SPECTROSCOPE

To the human eye, unaided by any artificial instrument, light was able to bring wonderful stories of color, form, and movement. When man began to aid his vision by mechanical means he entered a new world of knowledge and experience. The microscope made the tiniest and most infinitesimal objects visible, revealing in a drop of water or a grain of earth a world which would have been without its use entirely unknown to him. The telescope brought the most remote objects in man's universe to an appearance of comparative nearness. It remained for the spectroscope to translate into signs which scientists could learn to read the stories that light could tell of the physical and chemical composition, the temperature, and the rate of speed of worlds a million miles away.



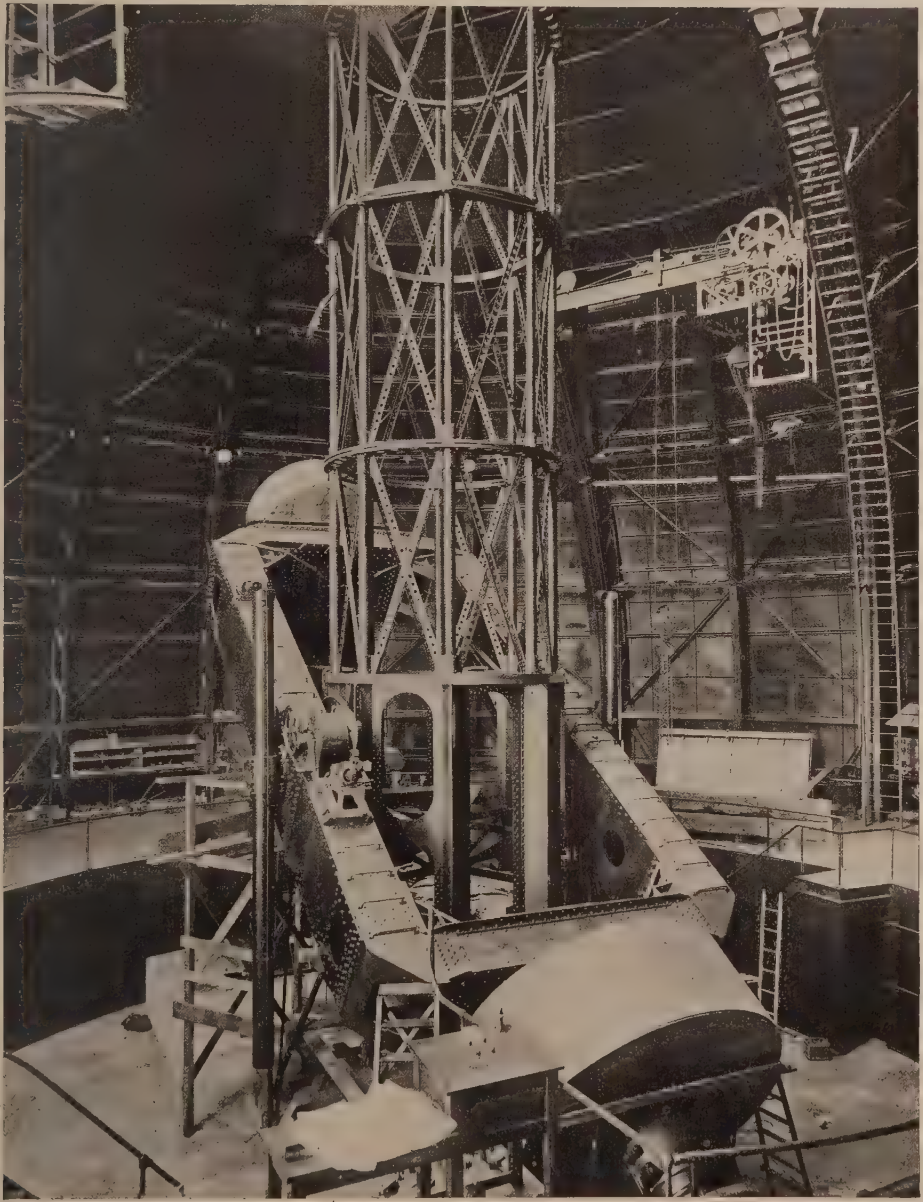
TOWER TELESCOPE AT MOUNT WILSON

This 150-foot tower is used for solar work. In the laboratory at the base of the tower an image of the sun about 16 inches in diameter is formed. Below this is a well 80 feet deep in which is set the spectroscope which completes the equipment.

In "The Earth A Storybook," Volume I, pages 95–101, is told the story of the make-up of a ray of light, as revealed by the prism, through which the different vibrations are thrown on the screen in the familiar spectrum of rainbow colors. From this simple experiment and the consequent identification of the solar spectrum came the intricate modern science of spectroscopy, a science founded on the study of the spectra of light-giving bodies.

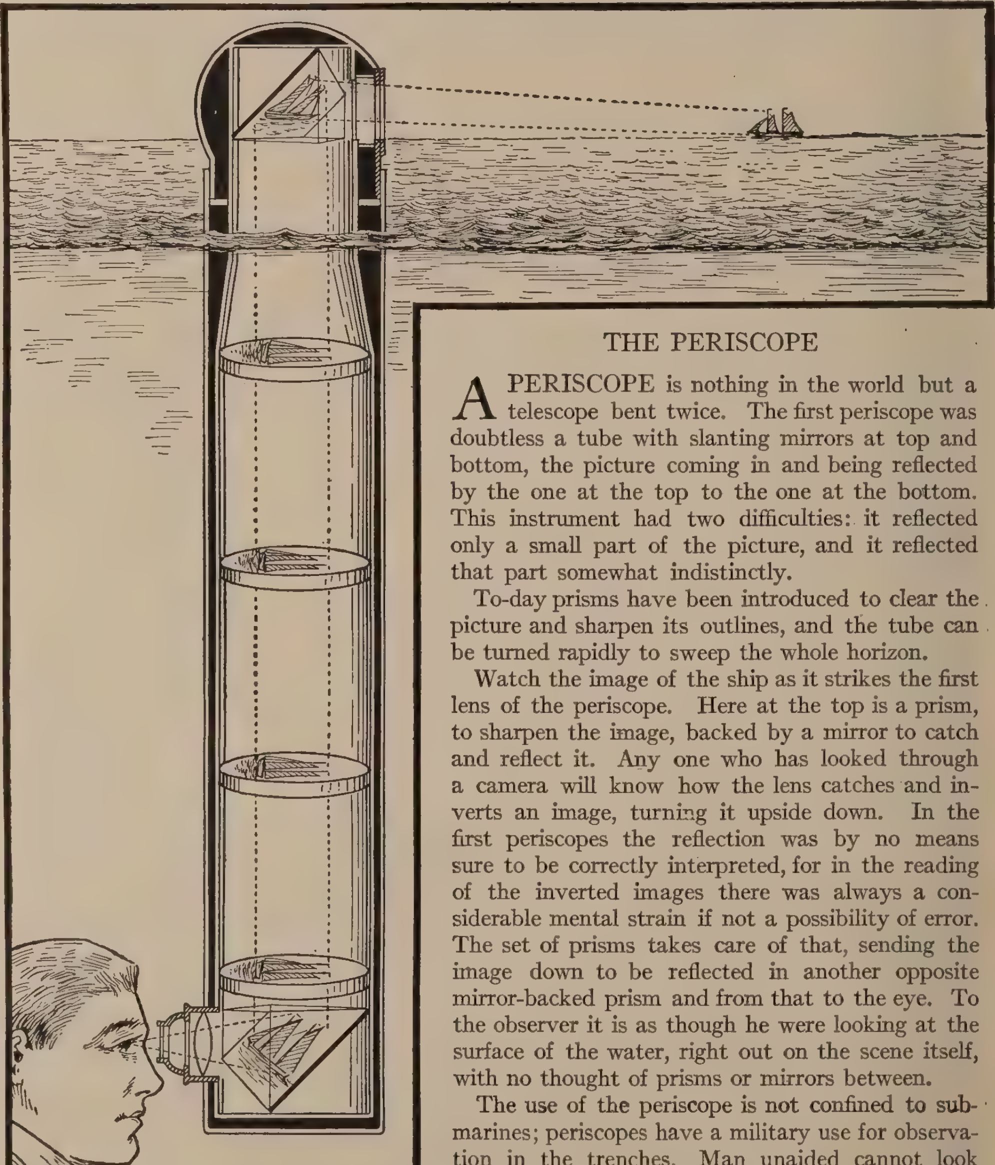
The spectroscope is an instrument consisting, in its simplest form, of a plate of metal with a very narrow slit in it through which light enters, a tube containing prisms or gratings through which the light passes and by which it is broken up or "dispersed," and a telescope to focus and magnify the spectrum.

The light from different sources varies when shown by the spectroscope. Sunlight, for instance, has always its complete set of rainbow colors in the precise order and amounts with which we are familiar. Gaslight has less of blue and violet. The story told by the strip of light from any luminous object is found to tell what the light-giving object is made of. Since each element, when luminous, has under the same conditions the same spectrum, and that spectrum is different from that of any other element, it is evident that if from a certain object you get the spectrum of a known element, you have proved the presence of that element in the object. For instance, the presence of certain features in the solar spectrum shows that the sun has in it sodium, iron, carbon, etc. The spectrum of a solid or liquid even at great heat is found to be continuous, without breaks, while that of gas consists of only a few bright lines. Therefore certain luminous objects in the heavens are easily identified as nebulæ, enormous clouds of glowing gas, while others are proved to be solid worlds. Temperature and distance are among the many conditions which make a difference in spectra. The scientist therefore reckons from careful observation and mathematical calculation the relative heat of distant worlds and their rate of speed. To be able without touching a substance to discover the elements of which it is made is to come as near to seeing the hidden things of Nature as any instrument invented by human ingenuity has yet attained.



THE 100-INCH REFLECTOR AT THE MOUNT WILSON OBSERVATORY, CALIFORNIA
See also Volume 1, page 60

THE EYE OF THE SUBMARINE



THE PERISCOPE

A PERISCOPE is nothing in the world but a telescope bent twice. The first periscope was doubtless a tube with slanting mirrors at top and bottom, the picture coming in and being reflected by the one at the top to the one at the bottom. This instrument had two difficulties: it reflected only a small part of the picture, and it reflected that part somewhat indistinctly.

To-day prisms have been introduced to clear the picture and sharpen its outlines, and the tube can be turned rapidly to sweep the whole horizon.

Watch the image of the ship as it strikes the first lens of the periscope. Here at the top is a prism, to sharpen the image, backed by a mirror to catch and reflect it. Any one who has looked through a camera will know how the lens catches and inverts an image, turning it upside down. In the first periscopes the reflection was by no means sure to be correctly interpreted, for in the reading of the inverted images there was always a considerable mental strain if not a possibility of error. The set of prisms takes care of that, sending the image down to be reflected in another opposite mirror-backed prism and from that to the eye. To the observer it is as though he were looking at the surface of the water, right out on the scene itself, with no thought of prisms or mirrors between.

The use of the periscope is not confined to submarines; periscopes have a military use for observation in the trenches. Man unaided cannot look around a corner, not to mention two corners. Whenever he wants to, he sets up his periscope.

PHOTOGRAPHS

DAGUERRE AND DAGUERREOTYPES

LIGHT and the lens give us many wonders, and of them all photography is one of the most interesting. In this, chemistry has come to the aid of the lens, however, else we should have in the camera as fleeting an image as that which the lens of the eye makes on the retina. Late in the eighteenth century it was observed that chloride of silver — horn silver, as they then called it — though white when first made and as long as kept in the dark, became purplish and finally black when exposed to the light. On this the whole science of photography is founded. Various experimenters worked with this substance, but it was the Frenchman Daguerre who finally triumphed and gave the world the first inklings of the process which has since become so extended and so generally used. The French government gave Daguerre and his partner a liberal pension for their discovery.

The picture was taken upon a copper plate and was in effect a crude tintype. It was not until nearly ten years later—Daguerre gave his discovery to the world in 1839 — that the collodion plate was invented, followed in later years by a great variety of other forms and improvements. In something less than a century the camera has grown, too, from a dark box with a hole in it and a simple lens in the hole to the splendid and efficient instruments in use at the present day, assisted in their work by a host of effective minor subsidiary inventions. Daguerre might well be astounded by the modern motion picture, even think it a product of witchcraft, yet he laid the foundation for it all with his daguerreotypes.

Progress in photography has come from the invention of the dry plate and the improvement in details of camera construction. Out of these inventions many new discoveries have come, most of them in the way of chemical formulæ which increase the sensitiveness of the plate, or in a knowledge of the nature of light and the laws of color, which have made it possible to correct the color irregularities of the ordinary photograph and even, in recent years, to photograph color itself.

MONUMENT TO DAGUERRE

National Museum, Washington.

THE DRY PLATE

The salts of silver, mostly nitrates and bromides, which are used to make a plate sensitive to light, must be mixed into some adhesive and transparent substance, so that they will stick to glass or to whatever support is used. For a long time photographers made use of collodion for this purpose. But such a plate had to be used as quickly as possible after it was mixed. Hence it came to be known as the "wet-plate process." Wet plates are still used by many photo-engravers, but practically not at all in the ordinary process of photography. The discovery that gelatine formed an emulsion with salts of silver that would not deteriorate for a long time, and hence might be allowed to dry and be kept for use for a considerable time, opened new fields to photography. In the

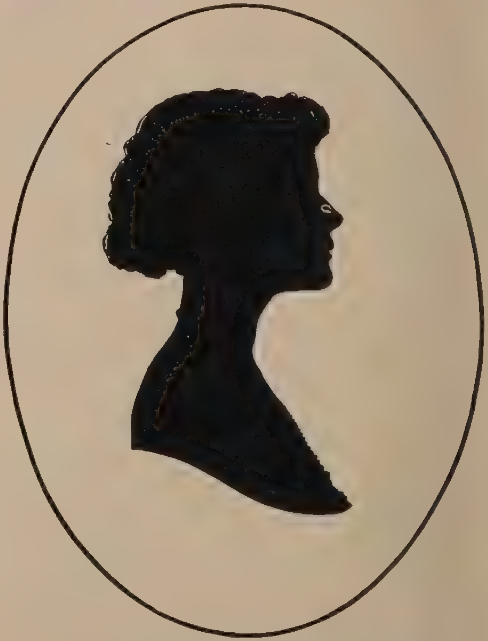
REPRODUCTION OF A "TINTYPE" OR FERROTYPE

old days the photographer had to carry a complete dark room wherever he went, and manufacture his plate on the spot, before taking his picture. Imagine a modern newspaper photographer sitting down with a complete dark room and making a plate before photographing a battle scene or a race! It was not long before these dry plates came into general use. Great factories were established for their manufacture, and the photographer no longer thought of making his own. Competition between manufacturers led to the steady improvement of these plates. Skilled chemists were hired to experiment with different salts, until a degree of sensitiveness has been reached that makes it possible to take a photograph by an exposure of $\frac{1}{1000}$ of a second.

THE STORY OF THE FILM

The ease and convenience with which photography can be practiced with the aid of the dry plate has led many persons to engage in it as a pleasure or pastime. This so widened the market for photographic supplies that manufacturers turned their attention to increasing in every way the simplicity and convenience of what is called "amateur photography." It was this demand that led to the invention of the film, which is made of celluloid, coated with sensitized gelatine. The film may be rolled or pressed into film packs, and with this convenience the photographer may travel, fully equipped. Portable developing outfits may be had to accompany these light field outfits, and chemicals are supplied that require only the addition of water.

Although we are all familiar with the "kodak" and the "film," few of us have heard of the man who took out one of the earliest patents for the film, Rev. Hannibal Goodwin, for many years rector in Newark. He spent nearly all the latter part of his life in research and experiment, working out gradually the principles of the invention. "Often enough," it has been told, "he came from the laboratory direct to his pulpit, with his hands stained and scarred by chemicals, standing out against his white surplice."



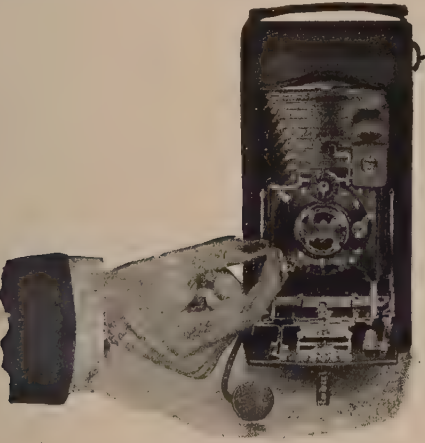
A SILHOUETTE

An early substitute for the painted portrait and the sole claim to immortality of the French statesman, De Silhouette, who invented it.

"It was Mr. Goodwin's love of children," his wife has said, "that prompted him to invent the film. He experimented in photography that he might display his pictures before the children of the Sunday school. He delighted in making pictures along Biblical lines, and these he would show through his stereopticon. The result was that whenever one of these entertainments was arranged by him every child in the parish flocked to the Sunday-school room. He was never happier than when surrounded by these little ones, and his one desire was to train them so that at a glance they could recognize any and all Biblical characters and subjects. He thought this the simplest and most impressive means of familiarizing them with the Bible; and he was right, for I well remember how letter-perfect the Bible classes of the House of Prayer were at that time."

THE SPEED SHUTTER

The most important change in camera construction since the days of Daguerre is in the apparatus by which the plate is exposed. In Daguerre's day, and for a long time afterward, this was done entirely by hand. To-day a spring shutter is used by which the time of the exposure can be regulated with the utmost accuracy. The focal-plane shutter, which is a curtain working directly in front of the sensitive plate, enables the photographer to make exposures of one twenty-five hundredth of a second. At this speed a cannon ball can be photographed as it leaves the cannon's mouth!



A FOLDING POCKET KODAK

This camera has a rising and sliding front, by which subjects can be photographed without tilting the camera.

PHOTOGRAPHY IN THE HOME

This snapshot was made possible by light reflection from below.

OTHER CAMERA IMPROVEMENTS

The qualities of compactness and lightness in camera construction have been so perfected that one can carry in one's pocket a perfect and complete camera with films sufficient for taking a hundred pictures and chemicals for their

A GRAFLEX CAMERA FOR NEWSPAPER MEN'S USE

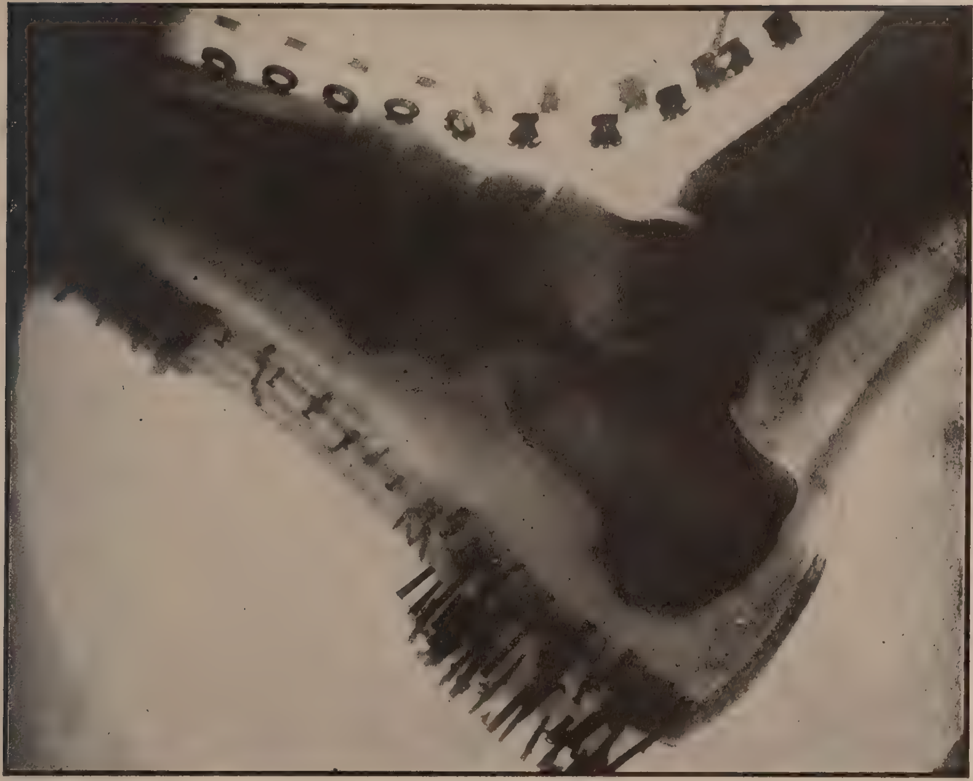
development. These cameras have all manner of convenient adjustments, and their working parts are as delicately made as the finest watch. The iris diaphragm enables the photographer to adjust the opening of the lens by the turning of a screw. His ray filters enable him to meet all conditions of color, and to take photographs of the most delicate clouds. The back of the camera swings so that he may slant his lens upward and still keep the plate parallel with the vertical lines of the object. In the cameras of the "reflex" or "graflex" class, the photographer may see the picture that he is taking while he is in the very act of snapping his shutter. It is difficult to see what advantage there could be in any further improvement in camera construction.

COLOR PHOTOGRAPHY

In the meanwhile, progress in the science of photography has kept pace with the progress in manufacturing cameras, plates, films, and chemicals. By the Lumière process, the colors of Nature may be photographed with remarkable brilliancy and truth. The secret of this method lies in the use of a ray filter which cuts out the ultra-violet rays of light, and of a plate in the gelatine emulsion of which colored particles of starch are suspended. These particles are of microscopic size and of three colors — green, violet, and scarlet. The combinations of

MOUNTING PRINTS ON CLOTH

The trays above the photographer's head can be lowered and loaded with prints.



REVELATIONS OF THE X-RAYS

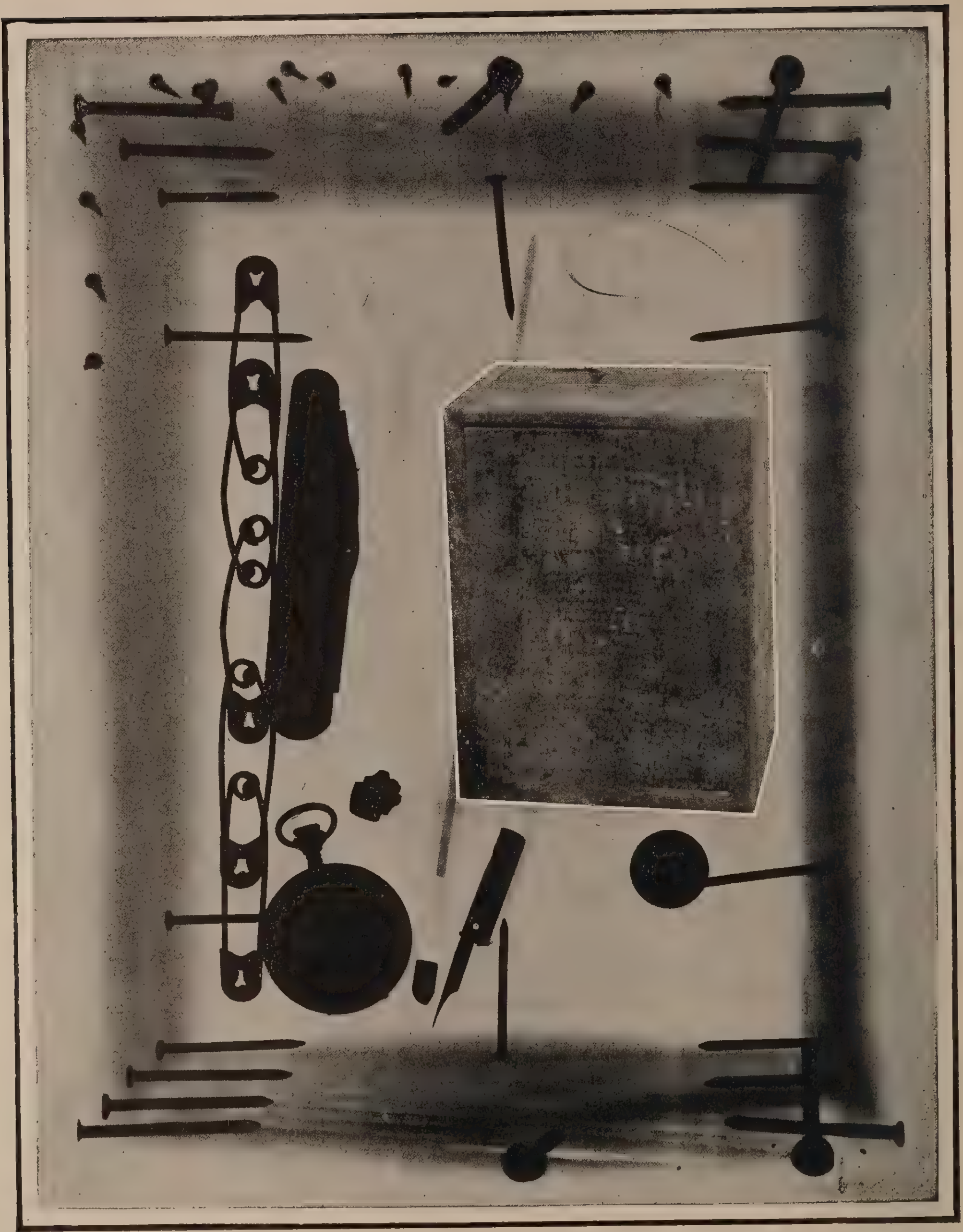
In this case, by means of the X-rays, the source of a severe pain felt by the subject when walking was shown to be an abnormal growth, or spur, on the heel bone.

these colors give all the colors of the spectrum, save certain tense violets. When the plate is exposed, the colored grain responds to its like and is made visible by the darkening of the silver which the emulsion also contains. The resulting negative must be "thrown down," or "reversed," by means of a chemical bath, and thus made positive. The result is a transparency in the colors of Nature, with the loss only of some atmospheric effects dependent upon violet light. In order to use this process one must be quite expert in the photographic art. Every reader of modern travel magazines knows, however, that constant improvement is being made. The color photograph taken direct from nature has come, and has come to stay. As yet its use is confined chiefly to professional photographers.

PHOTOGRAPHING THE INVISIBLE

IT was quite by accident that Professor Röntgen of the University of Würzburg discovered the X-rays. He was performing some experiments involving the discharge of electricity through glass bulbs from which all but a trace of air had been exhausted. When the new radiation appeared, it seemed to differ from light and all other radiations. That was the reason why Professor Röntgen applied the name "X-rays," X being meant to stand, of course, for an unknown cause.

This discovery was made in 1895, and since that time the strange radiation, with its peculiar name, has been put to many practical uses. The most interesting feature of X-rays



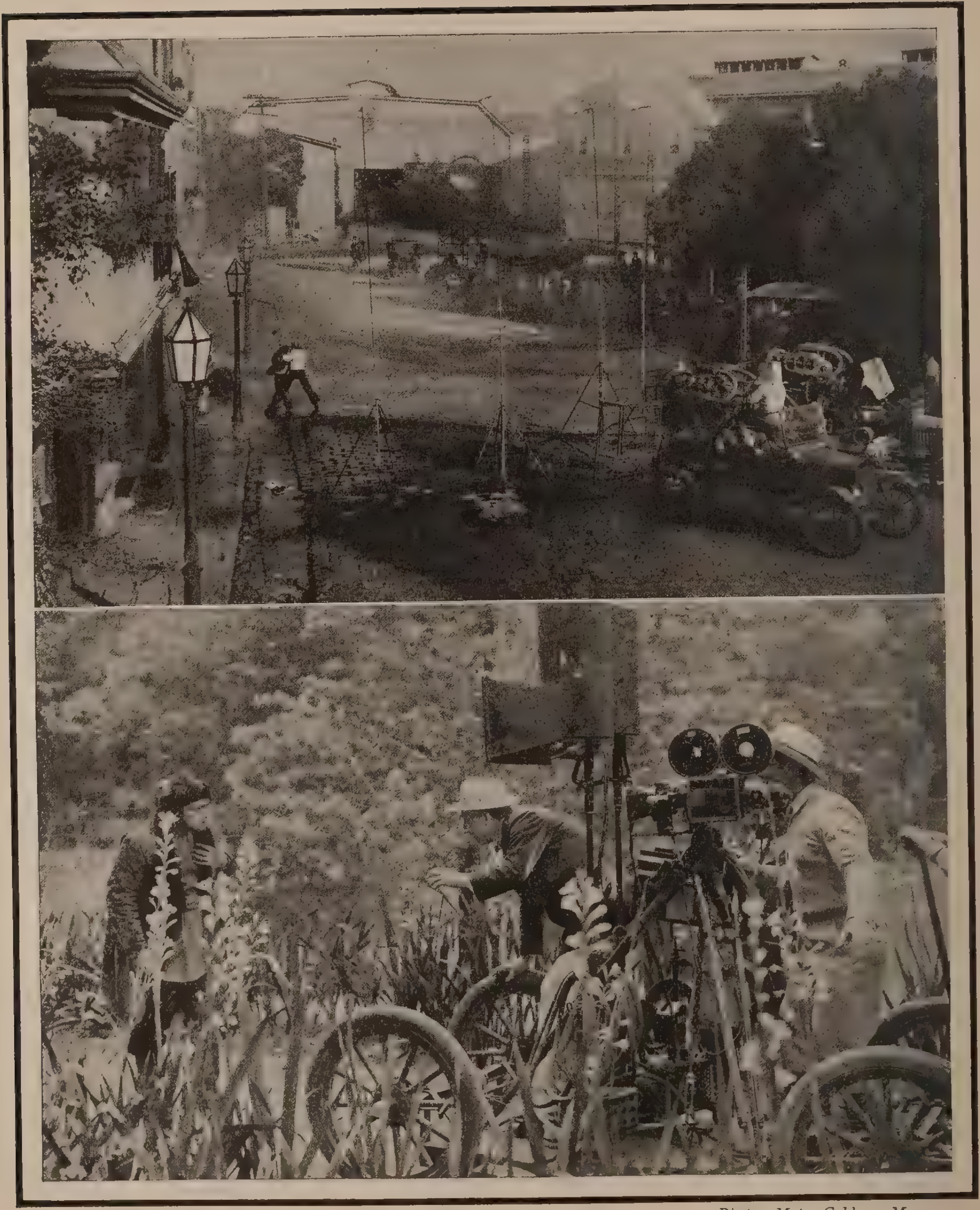
THE CONTENTS AND STRUCTURE OF A BOX AS SHOWN BY THE X-RAYS is the fact that they readily pass through substances which are entirely opaque to light, but are retained by materials through which light passes most freely. Glass, for example, which is always spoken of as transparent, absorbs the X-rays, but the rays are transmitted without difficulty through wood, aluminum, and human flesh. Great interest was manifested in the X-rays from the first, because of the fact that by means of them it was found possible to see coins in a locked box, the interior structure of a fish, and even the bones in a human body, the shadowy outlines being perfectly plain.

After a time it was found possible to combine photography with the X-rays, and then progress in the practical application of the rays became rapid. X-ray photographs are really shadowgraphs. If a human hand be pictured, very dark patches show the position of the bones, lighter patches show the muscles clinging to the framework of bones, and still lighter areas indicate the more transparent flesh. It is easy to understand that if a bone in the hand photographed is broken or if any abnormal condition exists, the shadow picture reveals the fact at a glance. For this reason X-ray photographs are extensively used by physicians and surgeons. Sometimes they are submitted to a jury as a very convincing form of evidence.

X-rays affect a sensitized photographic plate in precisely the same manner as ordinary light rays. These rays also have a very peculiar property. They are able to excite the fluorescent action of other substances, many of which are now known, so that they, too, will emit light. Certain of these substances are now commonly used in the making of special screens — often called "fluorescent" screens — on which the shadow pictures are cast when particularly accurate and clear images are required. When X-ray examinations are made directly, the room must be dark, and the operator usually prepares himself by remaining in darkness for ten minutes or more or by wearing dark glasses for some time, in order to protect his eyes. While the images are plain to any eyes, only an expert is qualified to report accurately on what is seen either on a screen or on an X-ray photograph. One must be perfectly familiar with radiographs of a normal structure before one can deal intelligently with those that are abnormal. Also, the X-rays must be used with a degree of caution. Many severe burns from these rays have been reported.

When X-ray pictures are made, an electrically lighted tube of special construction is used and the object to be photographed is placed between this tube and a sensitized plate. The plate is developed and printed from in the usual way. It may sound a bit startling, but it is a fact that in this manner a picture of a human skeleton may be obtained while its owner is yet alive. Using an X-ray machine in a darkened room, the action of the heart and lungs is plainly seen. The movements of the joints are made visible by the rays from the tube, glowing in green phosphorescence, while the spinal column and the ribs stand out boldly on the screen. Of course, the movements can be seen only by one on the spot, but the substitution of a plate for the screen gives a permanent record of all else that is seen. Sometimes the picture is made in daylight, which is quite possible if the plate is inclosed in some material which will protect it from the sun's rays. The X-rays will soon penetrate any covering of this sort. Formerly it was necessary to make an exposure of several minutes to get a negative by means of X-radiography, but so many improvements in the tubes have been made that now a few seconds often suffice.

When a radiograph of a man or woman is to be made, for a physician's use, all metal, such as buttons and buckles, and all articles of glass or bone are first removed from the subject's clothing. Plaster of Paris, adhesive plaster, and wood splints also interfere with the success of the work. Usually two views, say of a fracture, are taken from different angles, in order to secure an accurate record. X-ray pictures are often made use of in life-insurance examinations, and are employed for reference in hospital cases. By means of them the progress of a case may be shown and the study of difficult surgical problems greatly facilitated. It is probable that many possibilities in the use of X-ray photography remain to be developed.



Photos, Metro-Goldwyn-Mayer

MAKING MOTION PICTURES

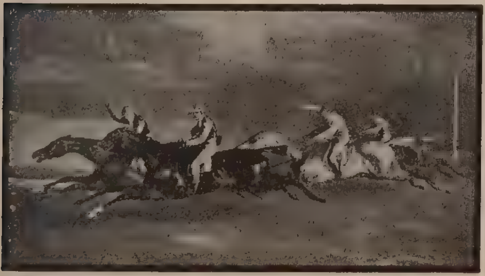
Top: Effect of rainy day being created by jets of water (at right) fanned into mist in which two figures (at left) are photographed.
Bottom: Motion picture camera on wheels, for outdoor use.

MOTION PICTURES

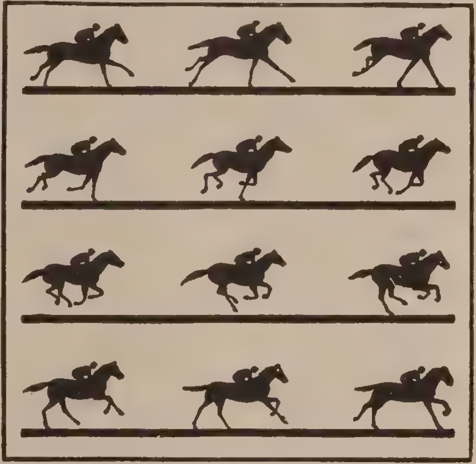
SO many wonders are worked by photography that we are stirred by a new one only when it is very wonderful. The motion picture has within a few years astounded and delighted the civilized world. That the people in a picture should move as freely and as rapidly as in real life is sufficiently surprising, but in the motion picture one sees veritable deeds of magic performed. Feats such as the conjurer used to perform before delighted audiences are tame before the magical transformations made visible by the motion-picture machine. By it strange and beautiful sights from all parts of the world are brought before the eye with photographic accuracy, and the moving film has become one of the greatest of educational forces.

THEIR INVENTORS

The world owes the sensitive film which makes motion pictures possible to George Eastman, who invented it in 1889, after long experiments with dangerous explosive chemicals. Its base is guncotton mixed with wood alcohol. The result is a polished, flexible, transparent, glasslike ribbon, which is delivered to the motion-picture maker in lengths of four hundred feet each. At first this film was very inflammable — explosive even — and had to be handled with great precaution. Later inventions have made it nonexplosive and almost noninflammable. Films of many widths are made for ordinary photography, but for the motion pictures they are all of one width — one and three eighths inches wide, of which three eighths of the width is given over to margins. The picture which is made, then, is just an inch long and three quarters of an inch high. It has to be exceedingly clear and sharp, as each picture is magnified twenty-seven hundred times when thrown on the screen. Every fault in the film is equally magnified, and the results must be very perfect to pass muster. Moreover, every machine must handle the film with perfect accuracy, for every false motion it makes is magnified as is the picture itself. As might be expected, the maker of such an accurate, painstaking machine is Thomas A. Edison, though the father of motion pictures is Edward Muybridge of Oakland, Cal.



A HORSE RACE AS PICTURED BY THE ARTIST

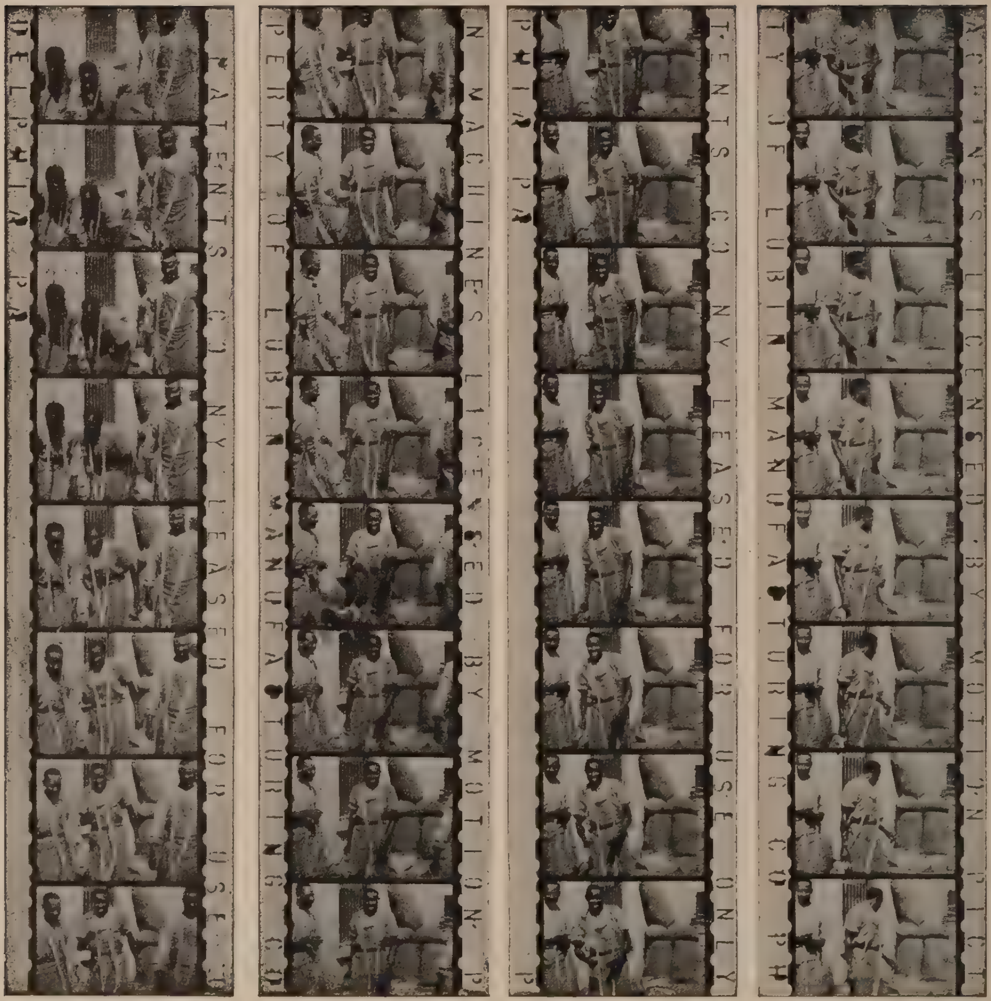


ACTUAL POSITIONS TAKEN BY A RUNNING HORSE

In 1872 Muybridge made successive pictures of a trotting horse in rapid motion — twenty-four of them. These pictures, placed in succession in a pile and riffled over so that each would be seen successively, seemed to show the horse in motion. But that was long before the time of the flexible film, and it was not until Eastman's invention came into use and was employed by Edison that the idea took real shape. The first motion pictures were shown at the Chicago World's Fair in 1893.

HOW THEY ARE MADE

And it all comes about because the image of an object which light makes on the retina



Courtesy of Lubin Mfg. Co.

PORTION OF A MOTION-PICTURE FILM

Showing its exact width, and the minute changes in each successive view.

of the eye lingers there a moment after the cause of it has passed on. The celluloid film made the moving picture possible. This, coated with the sensitized silver solution, is as transparent as glass after development, yet is supple enough to be bent and wound as if it were silk or paper. A very long film is wound by clockwork through a camera in such fashion that a single picture is taken while the film rests; then it moves on and another picture is taken and another, till sixteen have been taken in a single second. Each picture records a very slight change in the motion of the objects it depicts. When the negative film is developed and dried, it is used to print a positive film, just like a lantern slide, and this positive is put into a machine so that it passes through the space in front of a stereopticon lens in the same way that it went through the camera. Thus each picture is thrown for a fraction of a second, motionless, on the screen, then is quickly snatched away and the next substituted, and so on till all the reel is used up.

But because of the slowness of the eye to give up an image formed on the retina, each picture stays until the image of the next one has begun to form there and the changes of position in the picture move on exactly as in real life.

It is all very simple, but it is all wonderful, and the accuracy and cleverness of the mechanism which handles the film should come in for a fair portion of our wonder and admiration. Besides the phenomena of Nature the world over, the motion picture is delving into the wonders of life which are invisible to the naked eye. The lives of disease germs are watched through the microscope and thus photographed and shown in moving pictures to clinics of medical students.

ALL AROUND THE WORLD

The late lamented Captain Scott took with him on his first expedition to the South Pole a motion-picture apparatus and brought back accurate representations of the strange life on the frozen barrens of that hitherto unknown portion of the world. Edison sent a man from Capetown to the mouth of the Nile, photographing every form of life on the way, that children in school might see it in their study of geography — the giraffes and elephants of the jungle, the mining of diamonds, the beautiful blue Nile, the pyramids with tourists climbing them, and all the other wonders of that far-off land. The motion-picture producers have gone far beyond that. They employ armies of actors and attendants to reproduce plays, the staging of which often costs thousands of dollars. The subjects are not only such scenes as may be produced in a theater with all its tricks of scenery and lighting, or with an artificial outdoor setting, but great troupes of actors are taken to remote places where the natural surroundings are such as will best make the matter realistic.

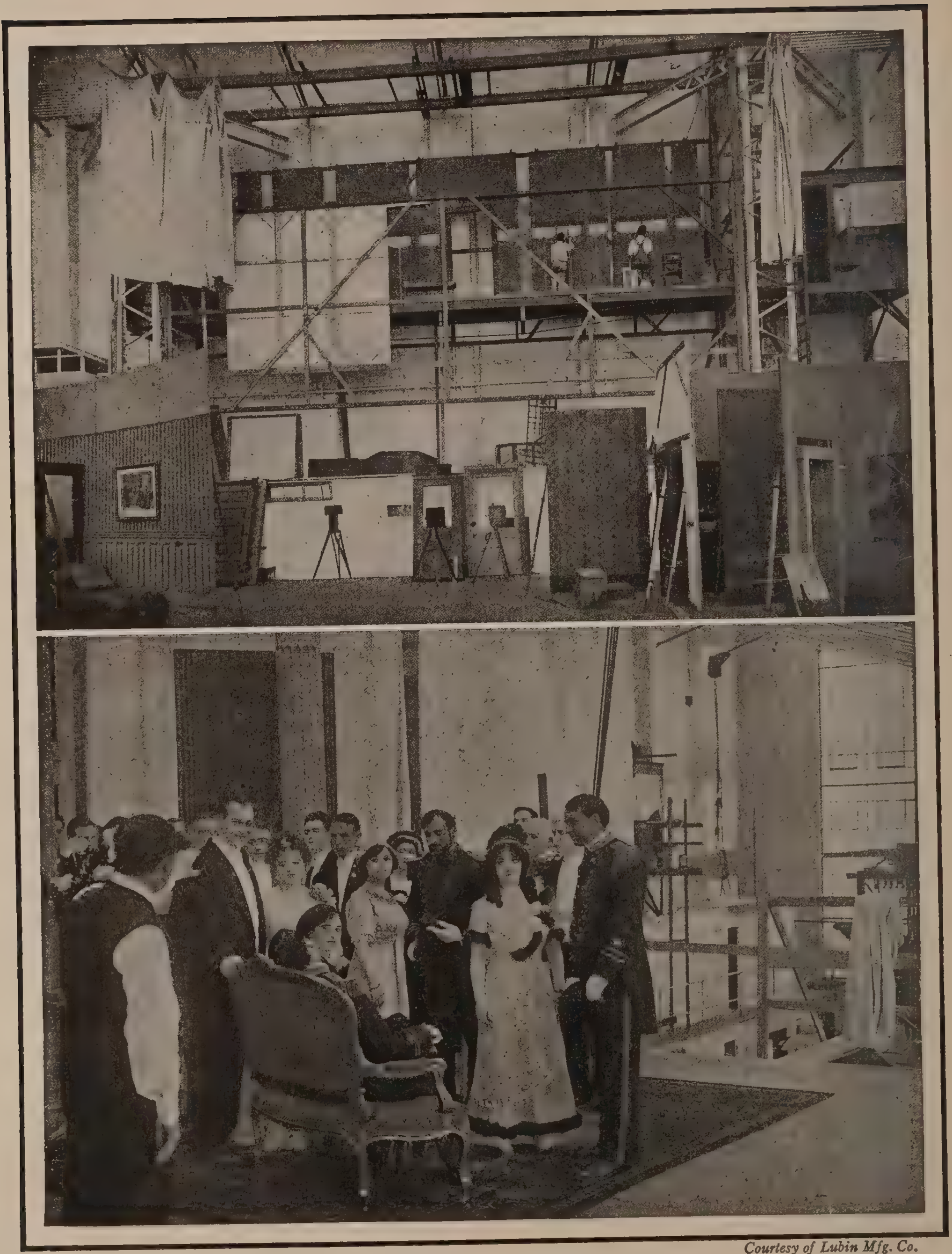
MOVING PICTURES IN COLOR

But now we come to the even more interesting question of how moving pictures are produced in all the variety of natural colors. This too, when it is explained, seems so simple that the wonder is it was not discovered earlier. The "three-color process," by which colored pictures in the magazines are now commonly printed, makes use of three plates, — one to print all the red there is in the picture, another to print all the yellow, and the third to print all the blue. (This is fully explained in Volume X.) When all three have been printed, one on top of the other, the "piled up" colors give us a fairly accurate color print. Colored pictures for public lectures have long been used, following much the same theory. Three negatives were used, one specially designed to "take" only the red elements of the picture, one the yellow, and one the blue. The lantern slides made from these negatives were all thrown on the screen at the same time, each slide using its proper colored light, giving a picture on the screen all in the natural colors. Thus we had a good colored picture but without any motion.

In the colored *moving* pictures, the first attempts were naturally to employ three distinct films, one for each of the primary colors — red, yellow, and blue — and by exceedingly delicate adjustments keep these three films operating in perfect unison. The difficulty, however, of getting machines of the required accuracy has led to a combination of the three films into one. On this one film each successive picture appears in triplicate, one taken for the red, one for the yellow, and one for the blue, and all are thrown on the screen at the same time. This film must therefore jump three times as far at each exposure as in taking the uncolored moving pictures. Though practically cutting the length of the ordinary film into a third of its usual length, these pictures are exceedingly accurate in their color values.

THE KINEMACOLOR PROCESS

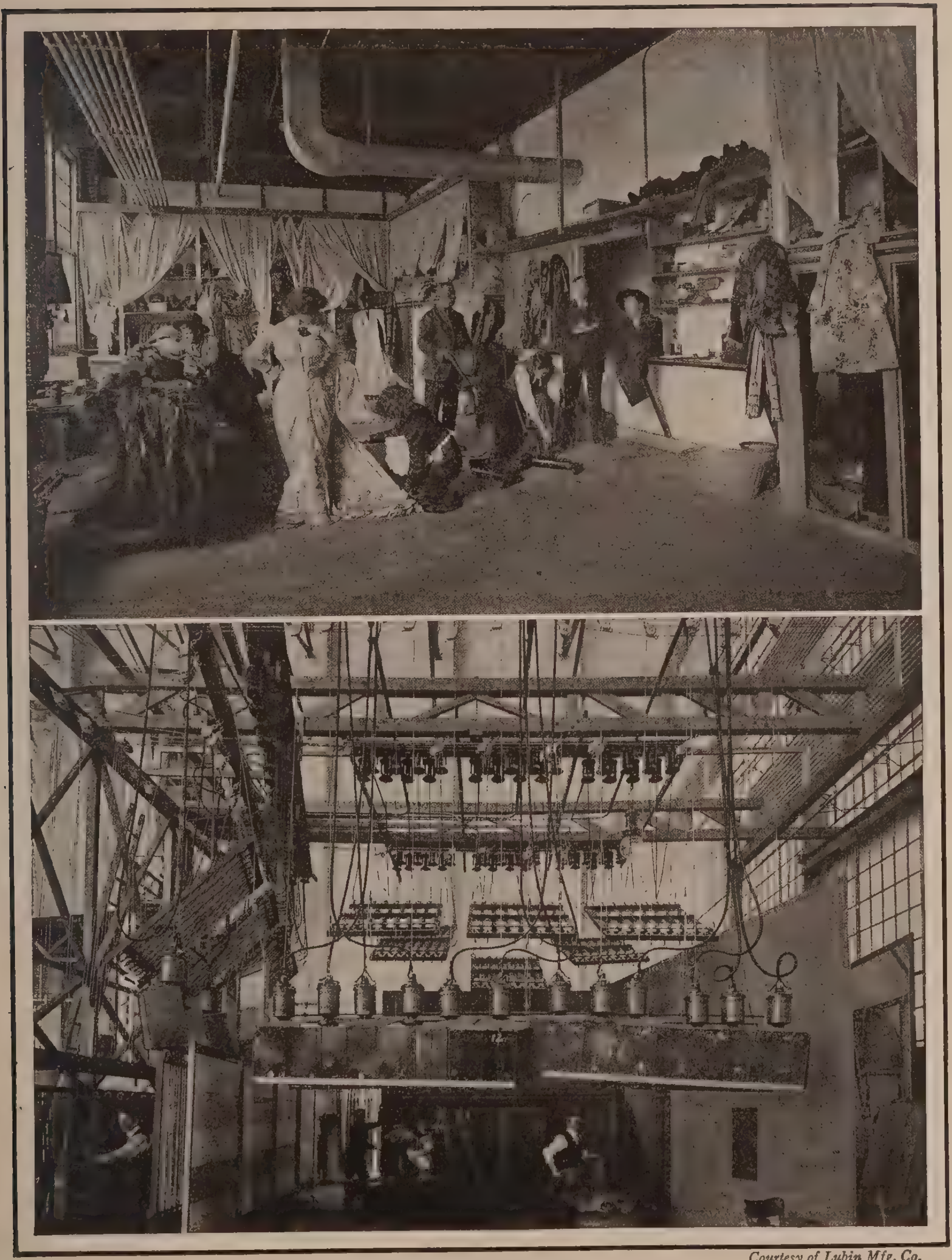
But the simplest of all moving pictures in natural colors, and the one which has met with most popular acceptance, makes use of the principle of "persistence of vision," that is, that the image made by any picture on the retina of the eye, as explained above, remains there for a few moments after the picture has itself been withdrawn. Thus if the proper red



Courtesy of Lubin Mfg. Co.

MAKING MOTION PICTURES

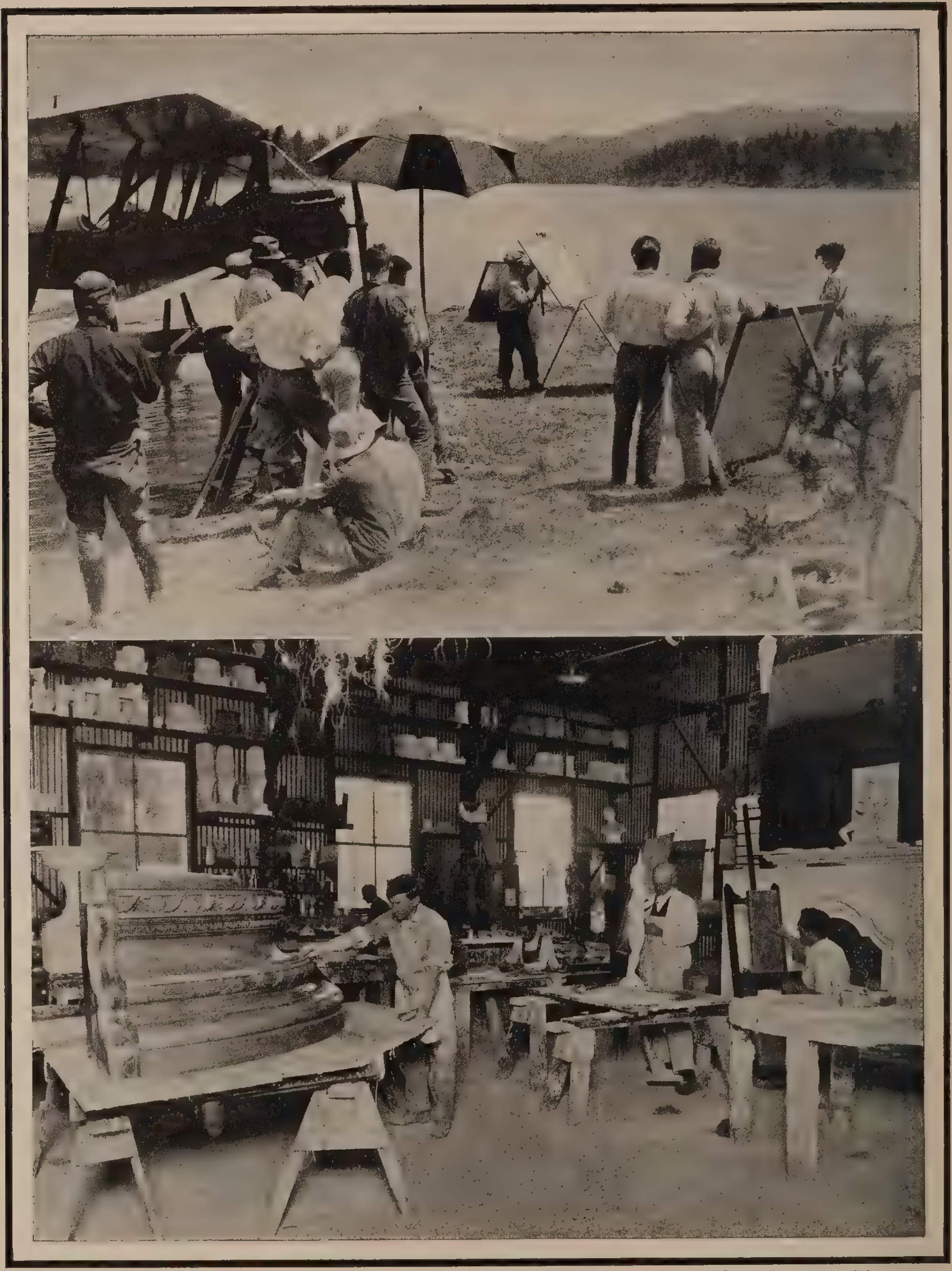
Top: Painting the scenes. Bottom: Rehearsing a play.



Courtesy of Lubin Mfg. Co.

MAKING MOTION PICTURES

Top: Wardrobe room where actors dress for their parts. Bottom: The lighting system of the studio.



Photos, Paramount Pictures

MAKING MOTION PICTURES

Top: Outdoor scene, with airplane. Note the use of reflecting screens for photographing the girl at the right. Bottom: Making models for scenery.

picture were quickly followed by the proper blue picture, and this in turn were immediately followed by the yellow picture, the colors would be "piled up" on the retina of the eye, and the eye would itself make the necessary combination of the colors. This is the principle of the kinemacolor process.

When the picture is being taken, a rapidly revolving disk brings before the camera shutter first a red screen and then a green screen (the latter being used in place of a blue screen and a yellow screen), so that the film when finished is made up of individual pictures alternately prepared one for the red light and one for the green light. By using the same sort of revolving disk when the pictures are being thrown on the screen, the resulting pictures are alternately red and green, but the eye very kindly composes the pictures into one, in which the colors appear almost as in Nature.

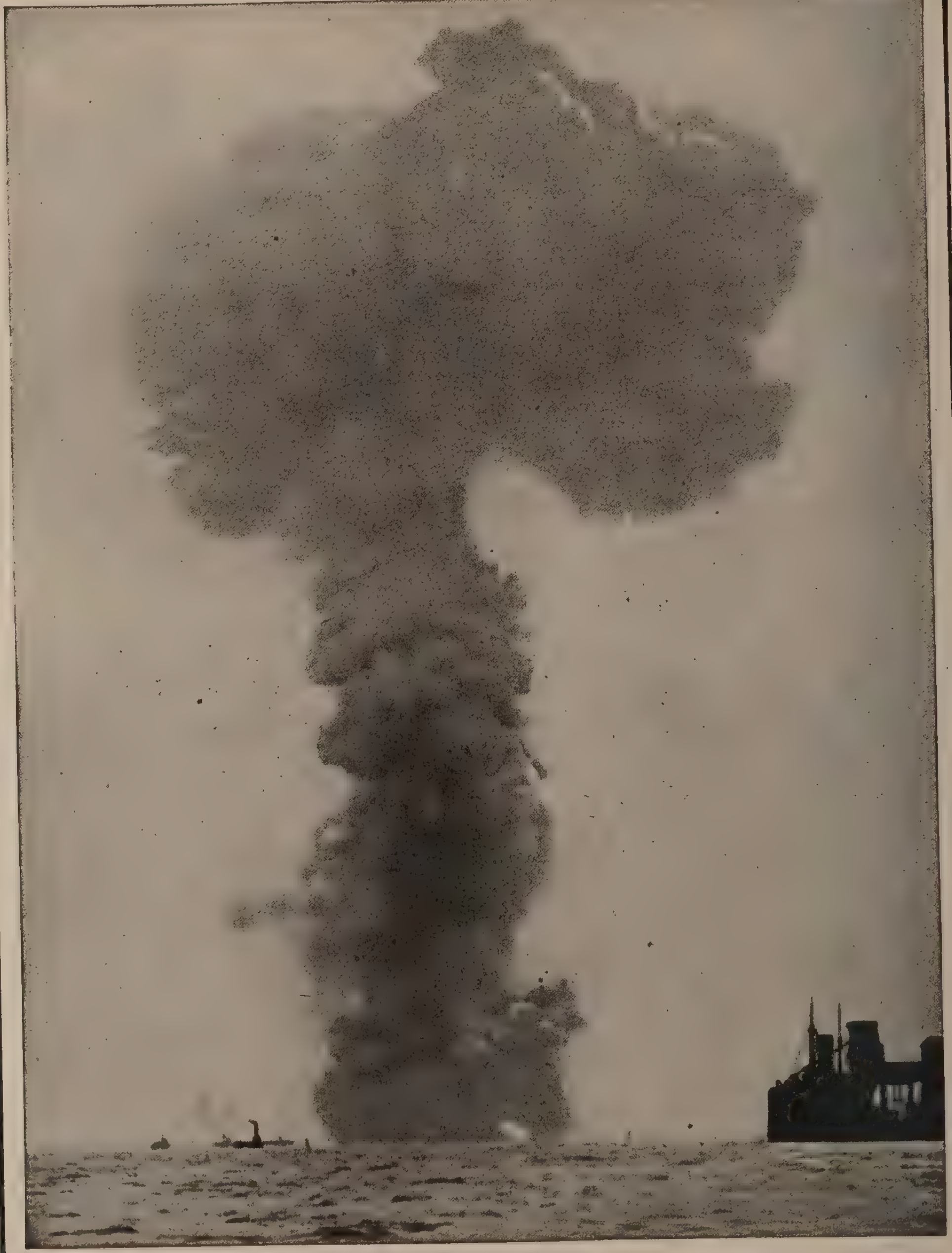
It should be said that the effort to use but two screens, employing the green in place of the blue and yellow, has resulted in giving the red and green shades a certain predominance in these pictures and in eliminating almost all the blue. But as the blue enters so largely into Nature, this manifest defect had to be met in some way. An inventive genius suggested that during the exceedingly brief interval between successive pictures, that is, while the film was being advanced from one position to the next, the curtain be flooded with blue light to see if the eye would not receive the blue impression and fit it appropriately into the pictures wherever it was needed. Experiment showed that the eye obligingly accepted the suggestion and did as was desired. This exceedingly peculiar adaptability on the part of the eye is doubtless due in part to the unconscious imagination of the observer and probably in part to the fact that the areas of the retina which have already received the strong red and green impressions are "busy" and do not notice the blue, while those areas on which the red and green impressions are not acting strongly can readily accept the blue impression.

A NEWER METHOD

Some of the color films which you have seen were probably made by a newer method, worked out after ten years of experimentation by a professor in a technical university. The scheme is so interesting as to be worth describing.

In this process only two colors are used to get the effect of six. From our color plate in Volume I we remember how the sun's light can be split up, according to its wave lengths, into the various colors of our spectrum. The two colors selected are a reddish orange and a bluish green. In taking the photograph a color camera is used in which the light rays are split or filtered. Back of the lens of the camera is a perforated mirror. By its means incoming light is split in half, one half being taken through a color filter which allows only blue-green light to come to the film on which the photograph is being made, the other half being taken through another color filter that permits only red-orange light to reach the film. As the film moves along, it gets constantly the two images, one below the other, one through the blue-green screen, the other through the red-orange.

When the film is taken from the camera, it has then a succession of these double images; but after it is developed, if it were printed, they would still be in black and white. This film is what the photographer would call "negative." A "positive" print must be taken from it for use in the moving picture machine. In the original film the two pictures taken at the same instant came one above the other; in the positive print one image must be directly over the other, or, in the photographer's term, must be superimposed on the other. This is done by printing the blue-green image on the front of the positive film, and the red-orange image of the same instant on the back of the same scheme. The film is then run through a dye bath of a solution of blue-green dye and red-orange dye. Here the marvelous result of the device comes. The blue-green dye "takes" only on the blue-green image, the red-orange dye on its image. The film emerges from the dye bath a colored positive print, ready for projection on the screen, which will give back, with only these two colors, the many colors of the original. While not yet fully perfected in its reproduction of certain tints, the process has already given strikingly good results, and promises even more in the future.



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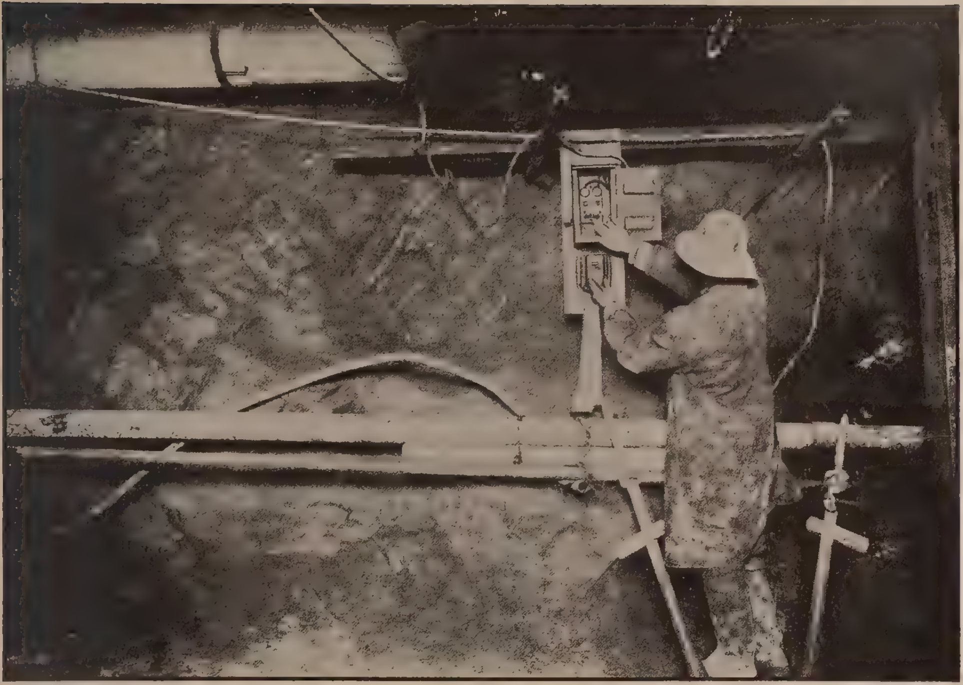
A DYNAMITE EXPLOSION

Photograph taken from a rescue boat bound for the steamship *Alum Chine*, on fire with 343 tons of dynamite in her hold. The explosion killed fifty-four persons and injured sixty, and did one million dollars' worth of damage to property.



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SETTING OFF A BLAST OF DYNAMITE BY ELECTRICITY

INVENTIONS FOR DESTROYING AND SAVING

EXPLOSIVES

FROM his very beginning man has found it necessary to use some sort of weapon either to defend himself from the attacks of wild beasts or others of his own kind or to procure food for himself. When fighting with an enemy or when attacking a shy or a dangerous animal, it became important to be able to wound or kill from a distance. For a very long time the bow and arrow, the spear, the hatchet, and similar weapons were the means by which this was done.

With the invention of gunpowder began a new era in the art of destroying life, and this explosive remained the one driving power of projectiles until as late as fifty years ago. The disappearance of the old flintlock was caused by the invention of the copper percussion cap of high explosive power, by means of which a blow could be made to fire the charge of gunpowder.

Not long after this, new and more powerful substitutes for gunpowder began to make their appearance. It was found that by using a combination of nitric and sulphuric acids to treat cotton a very powerful explosive could be obtained. This was called "guncotton." A year later the same acids were used with glycerine, and what is termed "nitroglycerine" was the result. The inconvenience of handling explosives in a liquid form caused inventors to use some granular substance, as infusorial earth, to absorb the liquid. This made a paste which, when molded into cylindrical sticks and dried, became the commonly used "dynamite."

On account of the suddenness of the explosion these new combinations were found to be too dangerous for rifle or cannon, and much experimenting was done to make the firing less rapid. This was accomplished by the addition of ordinary cotton or some other nonexplosive substance.

With the appearance of repeating rifles and machine guns it became necessary to do away with the smoke caused by the explosion of gunpowder. Most smokeless powders contain guncotton or nitroglycerine or both. Low explosives are formed from high ones by the addition of various substances, including paraffin, starch, bran, peat, and many mineral salts.

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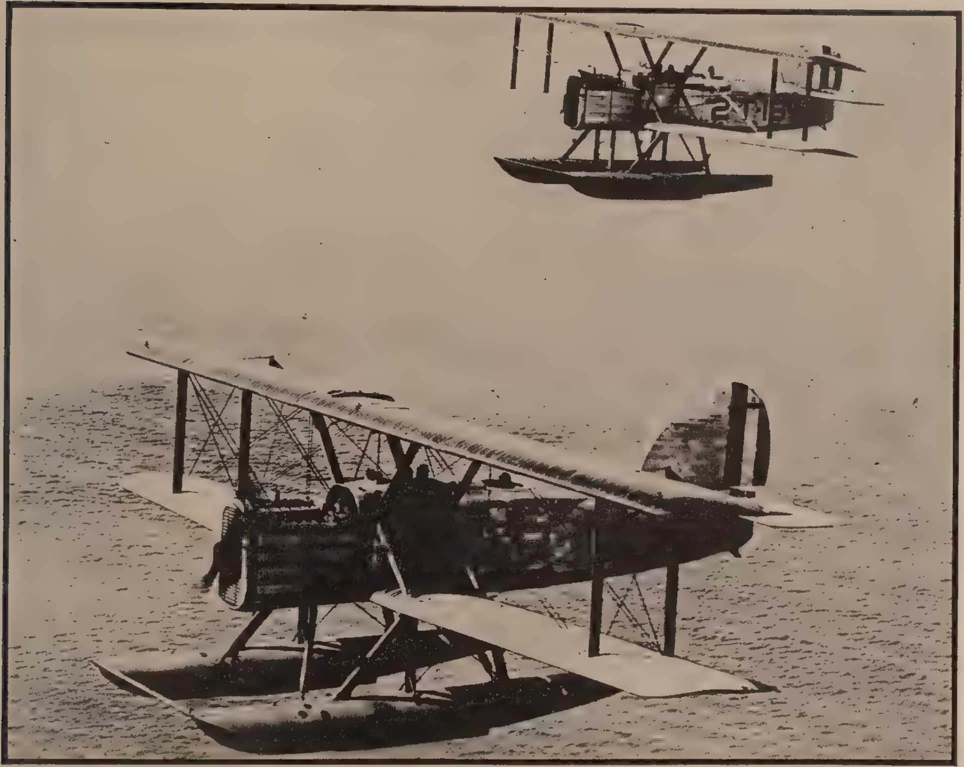
EXPERIMENTS WITH THE POWERFUL EXPLOSIVE CALLED "IMPERIALITE"

The lower picture shows Marquis Roberto Imperiali setting the fuse to eight hundred grams of the new explosive invented by him, at experiments held near New York, May 15, 1913. The central picture shows the twenty-five-ton granite bowlder shattered to atoms by the force of the explosive. The third picture is that of the inventor. Before setting off the blast, he pounded a handful of the new explosive between two heavy hammers, melted it into a vapor, and heated it gradually to 400° C. with seeming safety. A few days later, however, while at work in his laboratory, he was killed by the explosion of a small amount of his fatal invention, the secret of which he carried with him.

All the great nations have conducted with the utmost secrecy most extensive experiments in order to find an explosive more powerful than that used by anyone else. In all these experiments picric acid is used as the base of the explosive. This acid is formed by the action of nitric acid upon carbolic acid. One of the resulting explosives is called "cordite," and consists of nitroglycerine combined with other nitro-compounds and a mineral jelly like vaseline. It is semifluid and is made in the form of strings or cords. Hence the name "cordite." The British compound is called "lyddite," from its place of manufacture, Lydd.



Official Photo, U.S. Navy

POWERFUL TORPEDO PLANES

Swift, yet able to carry heavy loads of bombs weighing from 1500 to 2500 pounds.

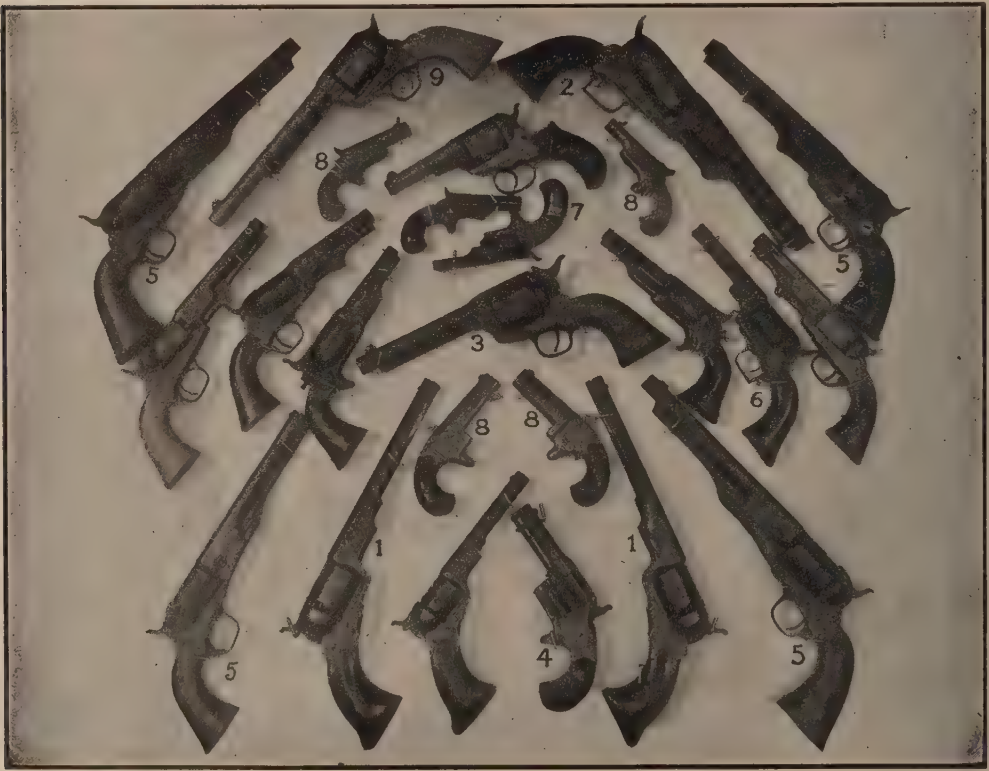
Two explosives familiarly known in the United States are trinitrotoluol (TNT), which is used in combination with other substances, and ammonium picrate, officially known in the army as "Explosive D." A great deal of experimentation has been carried on to get compounds of high-explosive content which would not freeze easily. The freezing point of nitroglycerin dynamite is at about 50° Fahrenheit, many degrees above that of water. Thawing of such a substance is accompanied with more or less danger. But non-freezing powders have been made which allow for safe road work and blasting at much lower temperatures. A waterproof powder has also been invented which can be submerged for twenty-four hours and then used immediately.

All these discoveries follow the experience of handling high explosives in tremendous quantities during the World War. The machine guns of that period, which so largely supplanted the shoulder rifle in many types of engagement, used great amounts. Barrage fire, under cover of which troops advanced for considerable distances, was spendthrift in the use of explosives. Invention at that time tended to quicker manufacture and greater safety in transportation and storage.

During the war bombs were much used in the defense against submarines, being of small size so that they could be easily dropped from destroyer, patrol boat, or airplane. Since 1920 large bombing planes have been built which are designed to attack battleships. The destruction which might be wrought by such devices in the event of war is one of the strongest practical arguments for world peace.

FIREARMS

BEFORE the advent of gunpowder the weapon most nearly related to a firearm was the English crossbow, which had a gunstock to be held against the shoulder similar to that of the modern rifle.

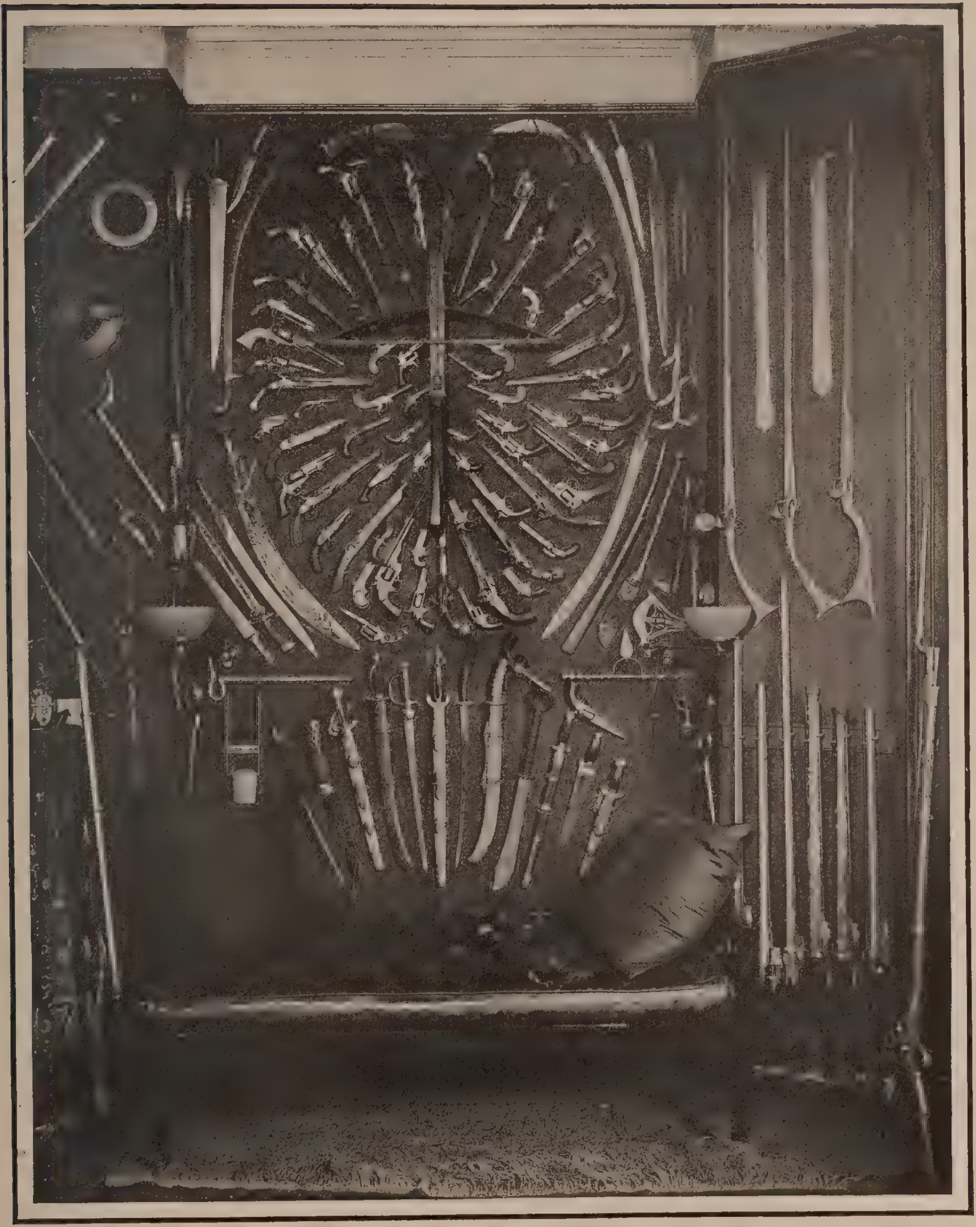


COLT REVOLVERS

A selection from the collection of small arms owned by Dr. James B. Thornton, Boston. 1, 1. Early-model Colt, valued by collectors at $500 to $1000 a pair. 2. Specially built .45 Colt, weighing, unloaded, four pounds and eight ounces. Carried by "Wild Bill" Hickok. 3. Gun carried for many years by Chief Iron Tail, who is supposed to have killed General Custer. 4. "Clover-leaf" revolver, long a favorite as a gentleman's pocket arm. 5. Heavy percussion six-shooter, of type used in the Civil War. 6. Special Colt built for Wells-Fargo Express messengers. 7. The first Colt cartridge revolver, which superseded the percussion gun. 8, 8, 8, 8. Derringer pistols, once popular pocket weapons in the South. 9. Texas cowboy gun, universally used on the border.

We are all more or less familiar with the old matchlocks and flintlocks used by our forefathers on both sides of the Atlantic. These were followed by the long-barreled, muzzle-loading smoothbore or fowling piece and the muzzle-loading rifle; for it was found that by cutting a spiral groove on the inside of the barrel of a gun shooting a single bullet the distance and direction of the projectile were vastly improved and the bullet, by revolving around its own center, kept its point to the front. The invention of the cartridge or shell caused the replacement of muzzle loaders by the modern breech-loading firearms. These have now attained a high degree of perfection in the repeating rifles and shotguns and the automatic quick-firing revolvers of to-day.

The then formidable muzzle-loading cannon and mortars of a century ago are now on the



WEAPONS OF VARIOUS LANDS AND TIMES

scrap heap, or as historical relics are keeping guard over public squares and burial places. In their place are the breech-loading guns which hurl projectiles weighing thousands of pounds and have diameters as large as sixteen inches, distances which are measured in miles instead of feet.

Explosive projectiles are now used which are capable of destroying a great modern battleship in less time than it takes to tell of it. These traveling explosives are also carried under the water by automatically working submarines called "torpedoes," which, attacking a ship invisibly from below, blow it into eternity in an instant.

Then there are the smaller rapid-fire machine guns, which, when a crank is turned, can be made to fire several hundred shots a minute. Indeed, invention and progress are probably nowhere more clearly shown than in modern warfare both on land and sea.

APPARATUS FOR WORKING UNDER WATER

EVER since men began to sail the sea in ships and were wrecked, untold treasure has been accumulating at the sea bottom. For centuries men have sought to find a way to get to this treasure and recover it, as well as to do work on the sea bottom. For this purpose the diving bell was first invented, by means of which many workmen descend in a room which is supplied with air from the top, and there securely work on the bottom of the sea. Men also go down in diving suits and spend hours on the sea bottom, doing work there which could be performed in no other way.

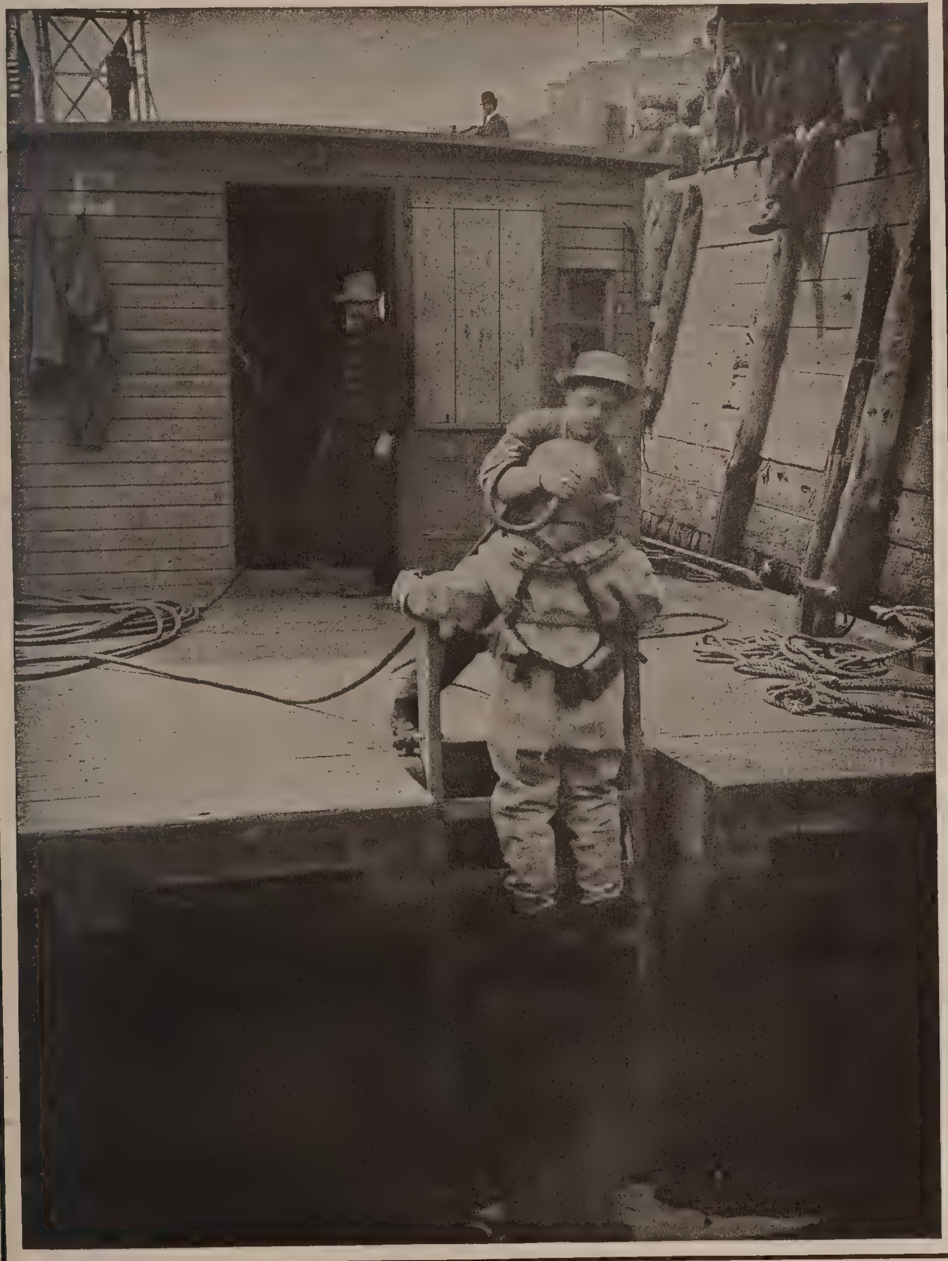
Water is nearly eight hundred times as heavy as air. If we take a hollow ball made of thin glass and force it below the surface to a sufficient depth, the pressure or weight of the water will eventually crush the ball. If an inverted tumbler is forced below the surface of water, the air caught in the bottom will be compressed as the tumbler descends, until the pressure of the air is balanced by the pressure due to the weight of the water at that depth. If a hole is made in the bottom of the glass and air is pumped in at this same pressure, the amount of air may be increased until it nearly fills the tumbler. This is the principle of the diving bell, which is like a square iron box without a bottom, the top and sides being fitted with windows protected by gratings. The air which is pumped into the bell from above also contains oxygen to keep the air fresh for the men to breathe. Inside the bell are fitted tools for working and a tackle for lifting and moving heavy objects. Among other uses to which this device is put is the laying of submarine foundations for lighthouses, breakwaters, etc. For this it is particularly useful.

It is generally necessary for the diver to have more freedom of action than is allowed him in the diving bell, and he then resorts to the diving dress. This is made in two principal parts, the helmet and the dress proper. A breastplate made of copper to withstand the water pressure has at the neck a screw bayonet joint. A corresponding screw is on the bottom of the helmet, which is also made of copper; and this may be attached or removed by one eighth of a turn. The rest of the dress, made of waterproof material in one piece for legs, arms, and body, is attached to the breastplate by another plate with bolts so arranged as to make a watertight joint.

The helmet is supplied with air through a valve connecting with tubes leading to the surface and the air supply. If this supply is accidentally cut off, the valve automatically closes, leaving sufficient air in the helmet to allow the diver to reach the surface.

One front and two side windows in the helmet provide means for observation. A telephone receiver and transmitter are ingeniously arranged within the helmet, so that continuous communication may be held with those above. Two weights of about forty pounds each are hung, one on the breast and one on the back, and the sole of each shoe contains about seventeen pounds of lead. An electric lamp supplied by current from above is sometimes used when work is carried on at great depths.

The water pressure to which the diver is subjected increases four and one third pounds per square inch for every ten feet that he descends. The ordinary working depth is about one hundred and fifty feet, though a depth of two hundred feet has been reached and work occupying several hours done in short relays



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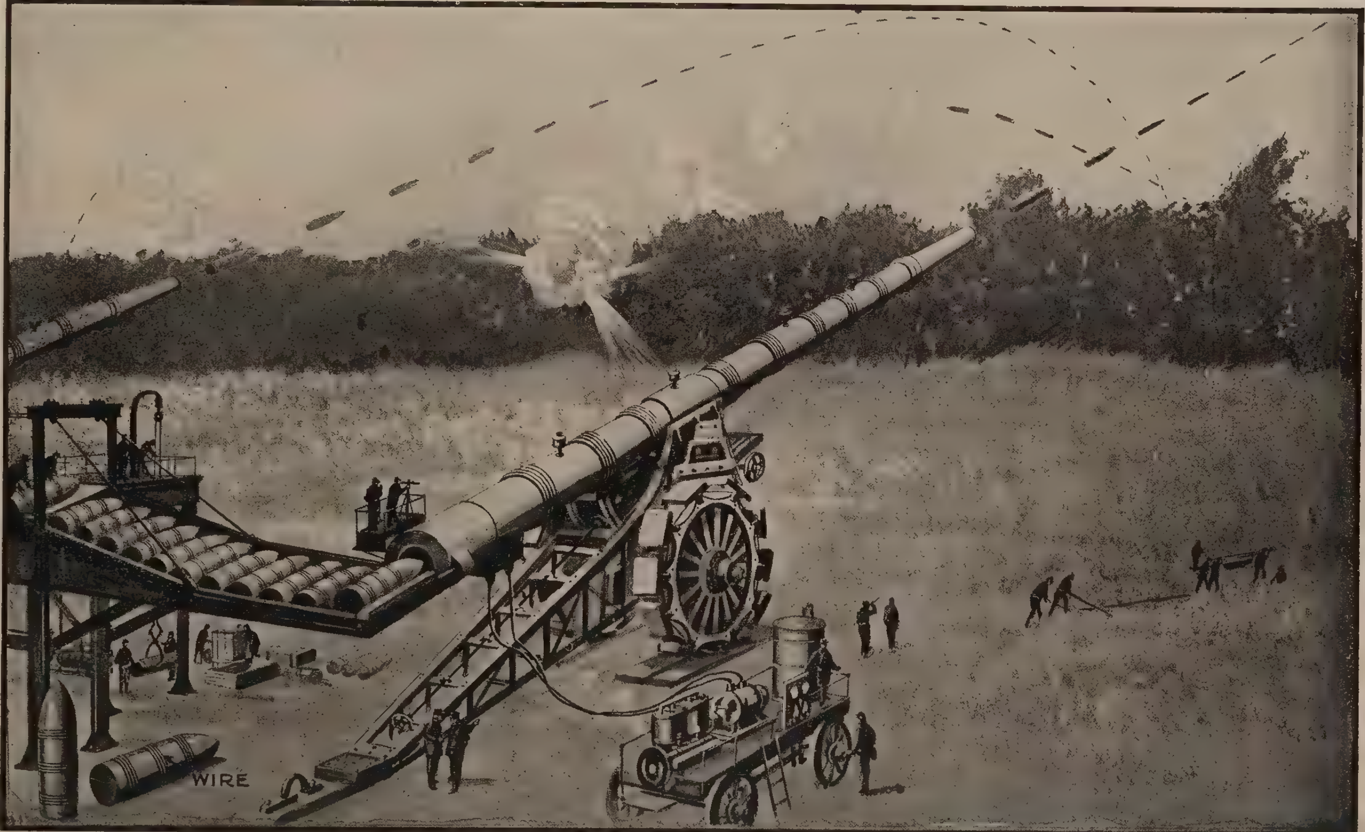
A DIVER JUST GOING BELOW

A HUNDRED-MILE ELECTROMAGNETIC GUN

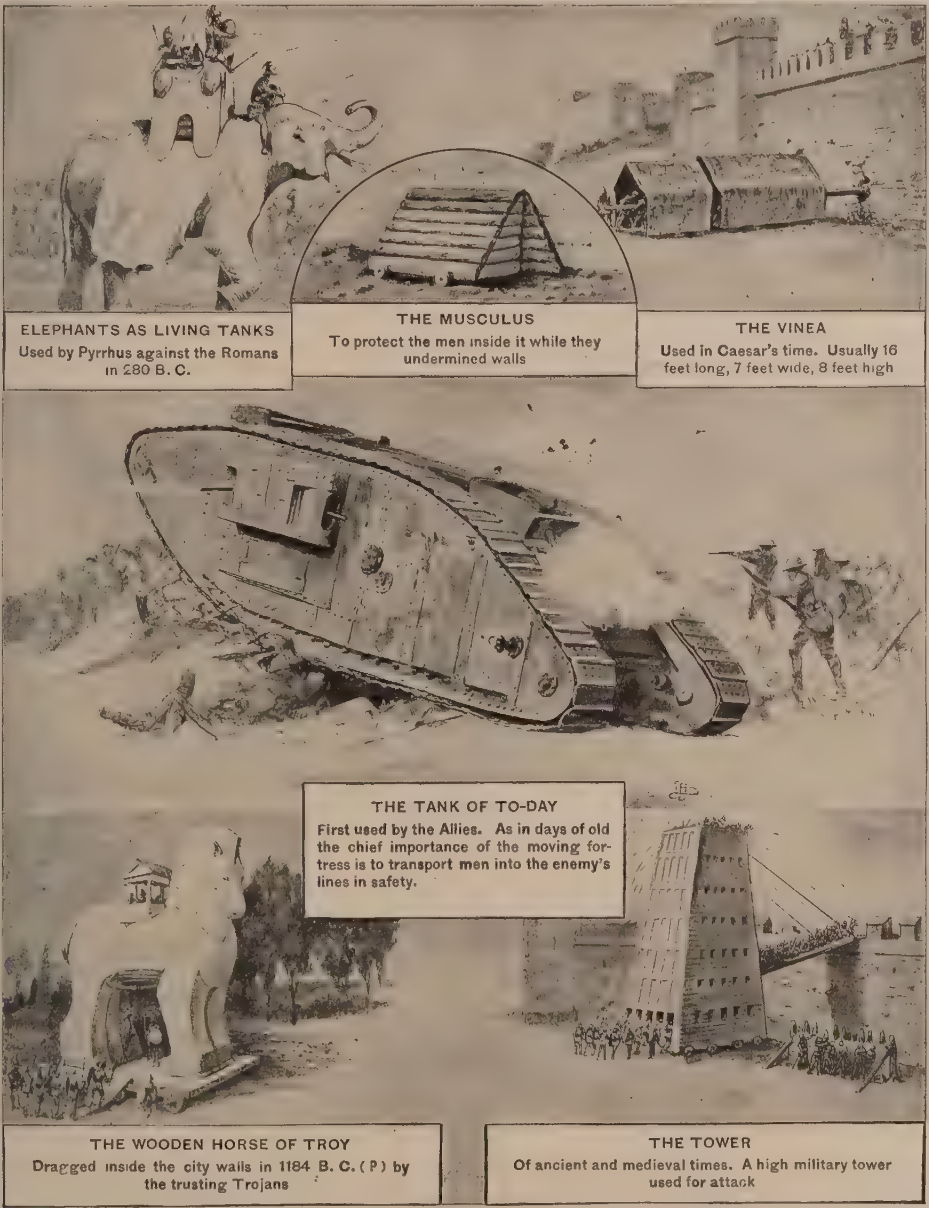


Courtesy Electrical Experimenter, N. Y.

A NINETY-FOOT GUN, CAPABLE OF LONG RANGE FIRE

If a gun like this could be constructed, it would throw 19-inch shells, each containing a charge of high explosives. See the curve taken by the shells.

THE TANK — 3000 YEARS AGO AND TO-DAY



ELEPHANTS AS LIVING TANKS
Used by Pyrrhus against the Romans in 280 B. C.

THE MUSCULUS
To protect the men inside it while they undermined walls

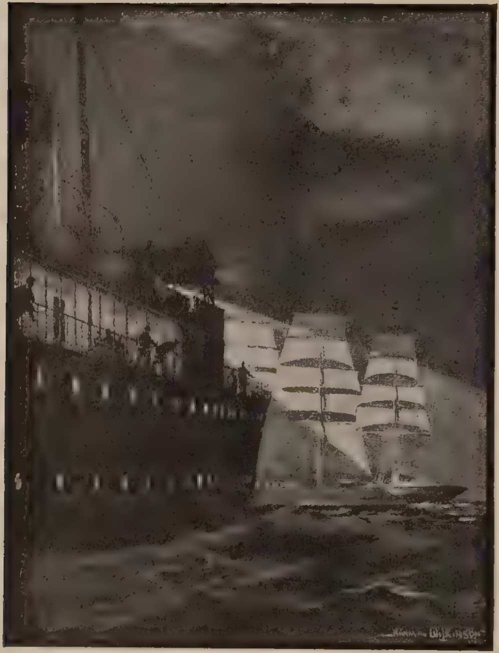
THE VINEA
Used in Caesar's time. Usually 16 feet long, 7 feet wide, 8 feet high

THE TANK OF TO-DAY
First used by the Allies. As in days of old the chief importance of the moving fortress is to transport men into the enemy's lines in safety.

THE WOODEN HORSE OF TROY
Dragged inside the city walls in 1184 B. C. (?) by the trusting Trojans

THE TOWER
Of ancient and medieval times. A high military tower used for attack

The strange moving fortress which struck terror into the hearts of the Germans was no new idea. The only really new feature of the modern tank is the manner in which it is propelled. The Greeks made the Trojans believe their horse to be a sacred image, and so gained entrance to the city they had long besieged. The Vinea and Musculus were built of heavy timber, covered with rawhide, the sides of the Vinea being sometimes of strong wicker-work. The Tower was sometimes ten stories high. All tanks carried men, many carried battering rams as well.



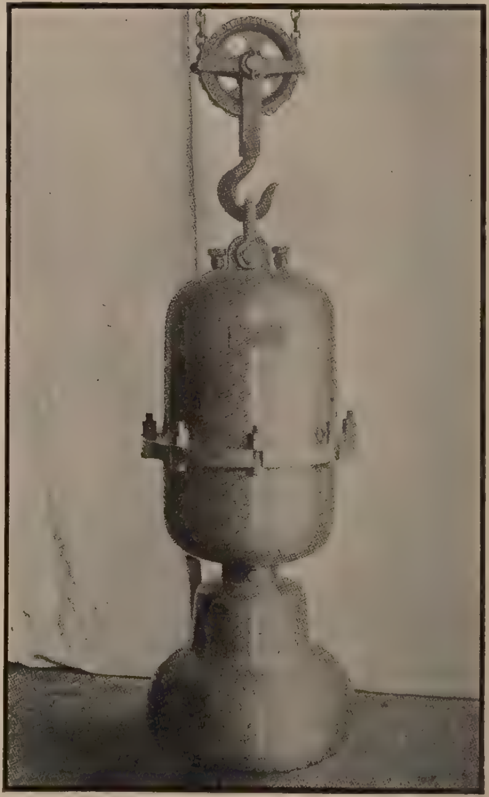
A STEAMER'S SEARCHLIGHT SHOWING A SHIP DEAD AHEAD

SIGNALING AT SEA

HOW to secure safety at sea has always been one of man's leading problems. In early times every ship that ventured from the shore was in danger of foundering or being driven to land in a storm; of being destroyed by fire or disabled and lost through accident; or of collision with the derelict of another ship. There was besides the ever present peril of running ashore or on rocks in darkness or thick weather. The earliest navigators planned to sail by daylight alone, in fair weather, and never out of sight of land. All these dangers still remain, but a series of inventions, of which submarine signaling is the latest, has provided every possible safeguard against them.

We have spoken of the mariner's compass as the first great boon to navigation. Its invention marked the close of one era and the beginning of another, that of exploration and colonization. The lighthouse (whose story is told on page 313 of Volume X) marked another great advance. Derelicts are now systematically hunted down and destroyed; iceberg lanes are fairly well charted, in their seasons, so that the mariner may be on his guard; through the progress of marine engineering storms are no longer a serious menace to the larger boats, and accidents to machinery seldom result in the loss of a ship.

However, with all these safeguards, fog remains a threatening problem. Because in thick weather the best light is dull or powerless, the foghorn and fog bell were developed to supplement it. Like the light, these are very efficient under favorable conditions, but both may be exceedingly unreliable. Often the foghorn is unheard when most needed, although the



A SUBMARINE SIGNAL

The information and illustrations relating to submarine signaling in this section have been secured through the courtesy of the Submarine Signal Corporation, Boston.

distance may be slight and the same sound may be heard by another ship at double the distance. Often the strongest light is strangely obscured. The cause of this seems to be the instability of air, the medium through which both act.

WHY DOES AIR SOMETIMES FAIL TO CARRY LIGHT AND SOUND?

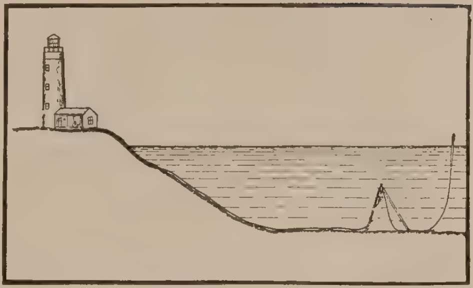
When air is of uniform density, sound and light waves proceed uniformly in all directions. But air is so lightly moved about, and so easily expanded and contracted, that its conducting power changes almost every moment. Sound waves, in particular, passing through air, do all sorts of queer things. So the sound of foghorns or fog bells may be faint or unheard, though the source is very near, or they may come to the ear from a false direction. Columns of air also play such tricks with light waves that the sight is deceived. Thus it comes about that in spite of the uncounted millions of dollars the world has spent in devising, installing, and maintaining these signals, every dense fog, every winter storm with its muffling snow and black vapor, wipes out these aids to the mariner and puts navigation back, so far as their aid is concerned, to the times of the Phœnicians.

WATER, A PERFECT SOUND TRANSMITTER

The idea of using the water as the medium for the transmission of sound was the key which opened the way to the development of a reliable marine sound signal. Water is uniform and transmits the sound equally in all directions. In telegraphy and telephony wires are used as a medium to transmit energy from one point to another. In wireless signaling we understand that ether is the medium by means of which energy is transmitted. In submarine signaling the medium for the transmission of energy from one point to another is water.

THE INVENTOR'S PROBLEM

The problem of the inventor was to devise an apparatus which would produce a sound under water that would carry for several miles, and corresponding means by which the sound could be heard on a moving ship. Because the sound had to be produced at a single point, but would be carried equally in all directions, the amount received at any point at a distance was found to be extremely small. It was therefore necessary to have a signal not likely to be confused with other sounds on a moving ship.



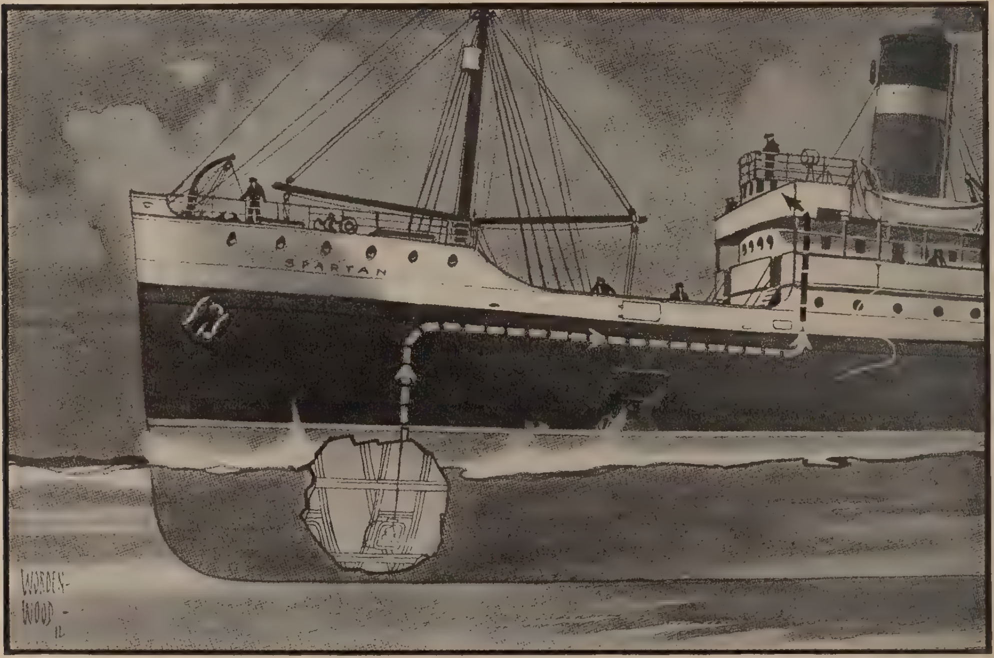
A SUBMARINE ELECTRIC BELL

These other sounds, which may be termed "foreign noises," are due to the rush of water by the ship and to the vibration of the machinery and of the ship itself, and are low in pitch. The signal, therefore, had to be made of high pitch, and after extensive experiments it has been demonstrated that sounds of about a thousand vibrations per second are most easily distinguished and most readily attract the attention. The submarine bells now in use, therefore, were made approximately of this pitch.

In developing receiving apparatus the problem was to pick up the sound which comes through the water to the side of the ship and transmit it to the navigator. This is done by an electrical transmitter, the microphone, or "small phone," so called because it intensifies and makes audible very feeble sounds.

BRINGING THE SOUND TO THE MICROPHONE

The submarine bell could start the sound in the water. A microphone could be placed in the ship. But how could the two be connected? The idea that would naturally suggest itself to the untrained mind would be to cut a hole in the skin of the ship so that there would be a clear path for the sound. But cutting a hole was plainly undesirable, and experience proved that it was entirely unnecessary. Owing to the great density of water, vibrations once set up in it were very powerful, so that the skin of a ship could take them up and pass them on. If a tank of water was placed just inside the wall of the ship, it received the vibrations and carried them on.



Copyright, Submarine Signal Co.

SUBMARINE SIGNAL RECEIVING APPARATUS

On either side of the ship near the bow and well below the water line is a small cast-iron tank filled with water, in which hang two microphones. The distance of the tank from the stem is twenty feet or more, according to the shape and size of the ship. Each microphone is electrically connected with an indicator box in the pilot house or chart room. The bell sound, coming through the water, passes through the skin of the ship, enters the water in the tank, and is picked up by the microphones, which in turn transmit it to the indicator box. Switches in the indicator box enable the observer to listen alternately to the sound picked up by the port and starboard microphones, and to determine by the loudness of the tone on which side the bell is ringing. In order to get the exact direction from which the sound is coming, the ship is swung toward the side on which the sound is louder and, when it is equally loud on both sides, the ship is pointing directly at the bell.

SENDING APPARATUS

There are four types of sending apparatus—pneumatic, automatic, electric, and hand. For lightships the pneumatic bell has been found to be the most convenient form, since lightships generally carry a store of compressed air. This bell, weighing four hundred and fifty pounds or more, is connected by a rubber hose with an air supply, driven by steam from the ship's boiler. At a place where there is no lightship, the bell buoy, operated by the motion of the waves, is used. For lighthouses and other places where neither of these pieces of mechanism is possible, an electric bell is sometimes hung from a tripod on sea bottom and operated by a cable conducting power from the lighthouse to the bell. This type of installation is used only at places where the depth of water is not over one hundred feet, where the tide is not swift, and where the bottom is sufficiently soft to allow the cable to embed itself. The hand bell may be used in emergencies from a disabled ship or from a breakwater or pier head.

Submarine signal bell stations are now in use on the coasts of the United States, Canada, Bermuda, England, Scotland, Ireland, the Netherlands, Finland, Sweden, Denmark, Belgium, France, Germany, Hindustan, Japan, and Uruguay, with more being added each year.

THE FESSENDEN OSCILLATOR

The most valuable sound-sending device is the Fessenden electric oscillator. Sound waves from a bell never reproduce in intensity the energy involved in the blow that set the bell vibrating; the sound as it comes to the listener is little more than a click. The oscillator consists of a large diaphragm, about two feet in diameter, which is vibrated electrically at a rate of 540 or 1050 vibrations per second. This oscillator is so much more powerful as a sender than a bell that it gives a range of twenty, thirty, and possibly fifty miles for under-water signals. Even more important is the fact that the sound waves from it can be broken up into a series of greater or less length to correspond with the dots and dashes of the telegraph code. Messages can be sent and received by the Morse code, even as they are over telegraph lines and by wireless. This means that vessels of a fleet can communicate with each other under water, that in case of a fog two vessels equipped with oscillators can locate each other and avoid collision, and that a submerged submarine can communicate with its mother ship in case of accident.

OCEAN DEPTHS MEASURED BY ECHOES

An interesting feature of the use of the oscillator is that by its means echoes can be received from sounds sent, and the distance of another object be determined by measuring the length of time elapsing between the sending of a sound and the return of its echo. In this way soundings have been taken of under-sea regions which could never before be accurately charted, and a clear and accurate map can be drawn of the mountains and valleys of the ocean's bottom. Since the direction from which the echo comes can also be noted, icebergs can be located in the same manner.

A SIMPLE DEVICE FOR SMALL BOATS

The latest development in submarine signaling is the development of a very simple device which may be used to pick up fishermen's dories or lifeboats lost in the fog. It consists of two parts,— a means for creating a sound which is operated from the dory or lifeboat, and a simple means lowered over the side of a fishing smack, or rescue boat, which will pick up this sound and from which the direction of the dory or lifeboat may be obtained.

The sounder is a cast-iron cone attached to a five-foot iron pipe. The cone is lowered several feet under water, and the upper end of the pipe is struck with a hammer. The receiving apparatus consists of a two-and-a-half-inch brass pipe in the form of an inverted "Y," through the shank of which run two small copper pipes, one running to one branch of the "Y" and the other to the other branch. These branches terminate in a round rubber cap about three inches in diameter. The tops of the copper tubes are fitted with a stethoscope similar to that used by doctors, one branch leading to the left ear, the other to the right ear. The apparatus thus gives a direct air path from the right ear to the rubber ball on the end of one of the "Y" branches and from the left ear to the other.

HOW DIRECTION CAN BE OBTAINED UNDER WATER

This inverted "Y" is then lowered into the water, and when the sound is heard so that it appears to the listener to be on his right-hand side, the inverted "Y" is turned toward the right until the sound appears to be on the listener's left hand. Then it is turned back until the listener gets the impression that the sound is dead ahead. In this position the arrow on the handle of the receiving apparatus will be pointed directly at the dory or lifeboat.

This method of obtaining direction is just what is done by everybody every day. You hear a noise which appears to be on your right-hand side; you turn your head toward the right, and finally the sound will appear to be coming from the left of where you are looking; then you turn your head back slightly until the sound appears to be coming from just where you are looking. This is because in the first position the sound arrived slightly earlier at the right ear than it did at the left and gave the sensation of being on the right side, then as the head is turned to the right far enough the sound will hit the left ear first and give the impression that the sound is coming from the left side. When the head is turned back until the sound strikes both ears at the same time, the source of sound will be directly in front of the head. This is exactly what is done with this receiving apparatus under water, and it gives a very simple and accurate method of obtaining submarine direction.

HOW SWITCHES AND SIGNALS ARE WORKED

RAILROADS, with their methods of operating, are discussed in Volume IV. Yet in this story of safety devices we must speak of the block system by means of which our trains are kept at a safe distance from one another on our crowded traffic lines. The old way was to depend on train dispatchers to regulate the distances between trains. Now, both human and mechanical means are employed to lessen the risk of collision.

THE BLOCK SYSTEM

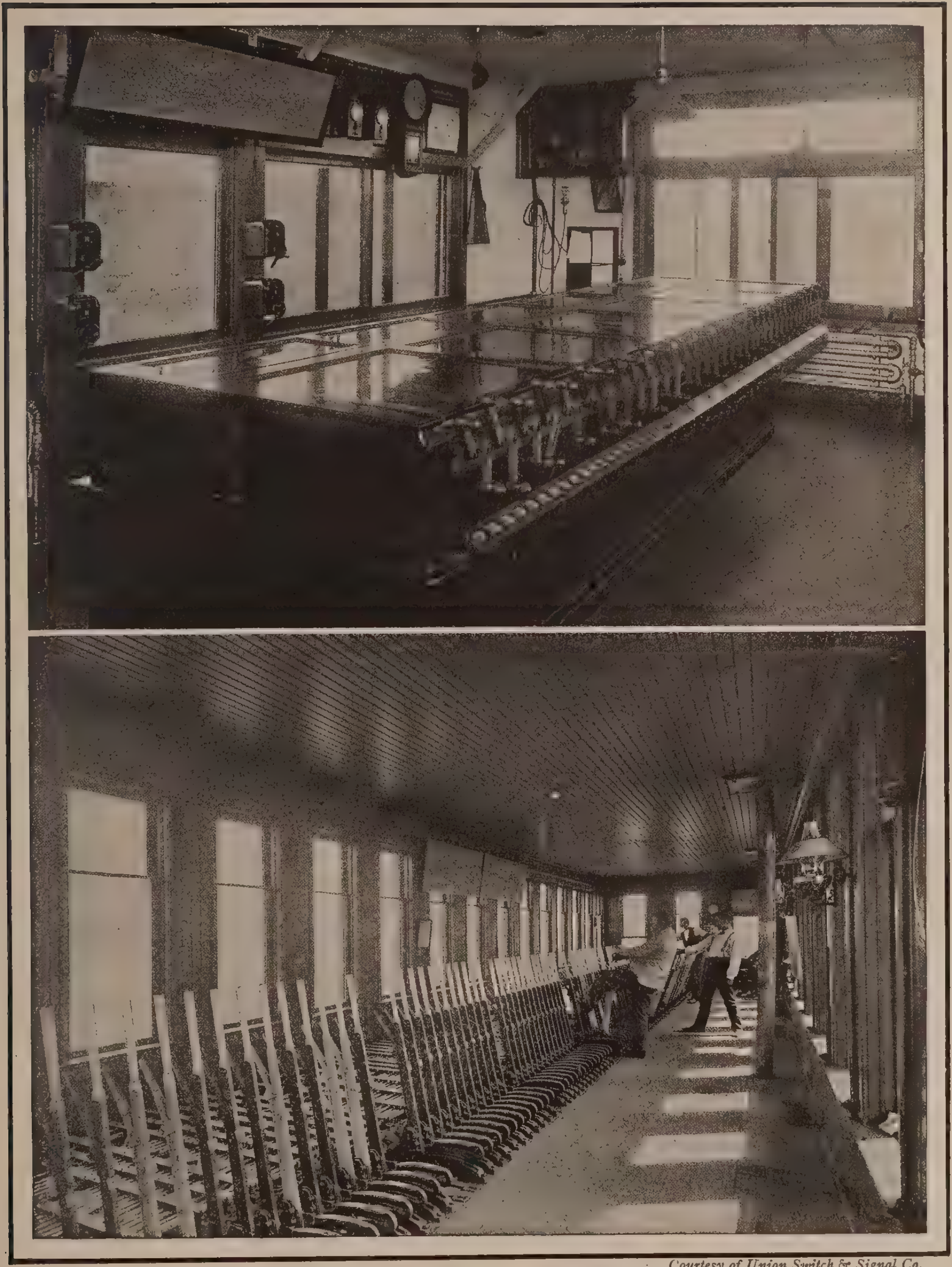
By the block system the line is divided into a number of sections or blocks from one-half to five or six miles long, and while a train is on a block no other train is permitted to enter it from either end. At the end of each block is a signal cabin in which a signal man is stationed at all times. The cabins are connected by telegraph or telephone, or simply an electric bell signal with a code is used. At each cabin signals called "semaphores" (as shown in the top picture, page 190) are used to indicate to approaching trains whether to proceed into a clear block section or to stop and wait for the train ahead to pass out of the block.

On many roads in the United States, however, automatic block signals, controlled by electromagnets, are now in use. These do away with signal men at the ends of block sections and afford protection against obstructions on or breaks in the track. They are likewise less expensive to keep up.

OPERATING THE SWITCHES AND SIGNALS

A switch is a device for moving a small section of track so that trains may be switched, run, or "shunted" as they call it in England, from one track to another. All switches and signals are controlled by levers. Where switches and signals are closely grouped, the levers are also grouped, and are operated from a central station or tower. In this tower is placed what is known as an interlocking machine (see pictures for the various types), consisting of a row of levers the movement of which causes a corresponding movement of the switch rails or signals, and are so interlocked with each other that it is impossible for the operator to signal two trains which might run into each other.

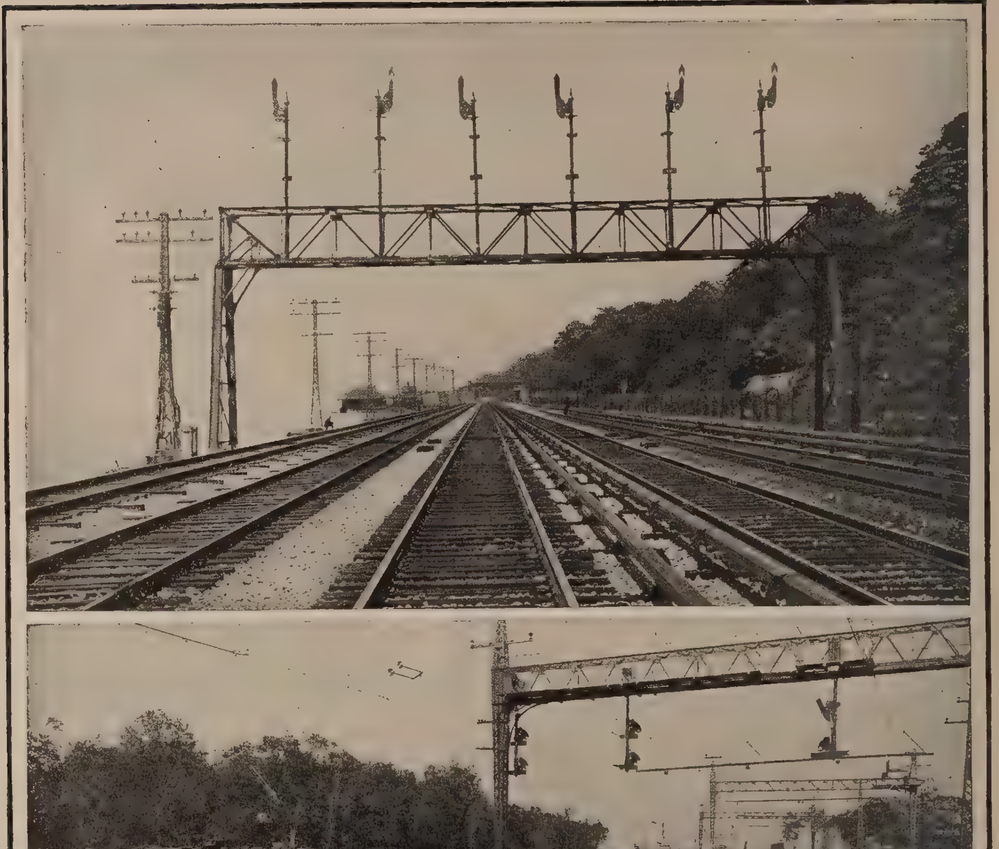
There are two methods of working the levers: one mechanical (the older system), and the other using compressed air controlled by an electromagnetic valve from the lever or by electricity. Where the operator supplies the power, as in the mechanical system, the levers are long and substantial, so that he can exert considerable power through them. This power is supplied by means of rods and cranks to the switch rails or the signals, causing a movement to correspond with the lever. Where compressed air or electricity is the source of power, the levers can be made very much smaller and one operator can handle a very much larger machine than with the older system. For this reason and other advantages "power-operated interlockings," as they are called, are rapidly displacing the mechanical system.



Courtesy of Union Switch & Signal Co.

SWITCH-OPERATING ROOMS IN SIGNAL TOWERS

Compare the small size of levers used in an electric or electropneumatic system, above, with those used in a mechanical system, below.



Courtesy of Union Switch & Signal Co.

RAILROAD SIGNALING DEVICES

Top: Semaphores on New York Central road. Bottom: A power-operated movement attached to the tracks.

GRADE CROSSINGS

But while railroads have solved with considerable success the problem of running engines and trains on their own tracks without collision or dangerous interference one with another, they are confronted in this modern age of motor traffic with the far more difficult problem of dealing with the public as they drive high-powered engines across their tracks.

In the old days when the circuit of a man's natural journeyings lay within the bounds of a region with which he was reasonably familiar, the grade crossing was only moderately dangerous. Always the driver who was to cross a railroad track must be warned, but he was driving slowly and could probably be warned in time. To-day the situation is entirely changed. Motorists are constantly travelling on roads with which they are totally unfamiliar, and travelling at a high, often a reckless rate of speed. The newspapers keep us all too well informed on the tragic results in death and injury to automobilists caught on the tracks by a passing train. The engineer, as he scans the track in front of him, has a new and constant dread lest at any grade crossing a careless or unsuspecting automobilist may be disputing with him the right of way; and while the automobile might have had time to stop in time after seeing the train or hearing its signal, the swift-moving express train, driving forward on its required schedule, can rarely be slowed down in time to avoid disaster.

The simple solution for this problem is the elimination of the grade crossing, that crossing at which a highway intersects a railroad track on the same level. But the simplicity is only theoretic, for there are hundreds of grade crossings which it would mean enormous expense to remove. The railroads are coöperating with communities in getting rid of the most dangerous or most congested of these danger-spots. They are also placing more and more men with traffic gates at populated corners, and are installing elaborate systems of warning bells and signs on country roads. Yet with all these devices, the danger remains and can be met only by caution on the part of the driver on an unfamiliar road and by a close observance of all warning signs or sounds. It is for the public-spirited citizen in every region to consider his own territory and join wholeheartedly in any sane and sensible crusade which may be appropriate there for the reduction of this danger.

TRAFFIC SIGNALS

If trains are a danger to motorists, their fellow automobilists are an even greater danger. Here the public is taking a strong stand, with measures which are beginning to show results.

The "silent policeman," that signal box which flashes its lights at regular intervals, allowing traffic to proceed or pedestrians to take their turn in crossing, is one of the most interesting of the modern devices. Who has not seen a motorist stop on an entirely empty road and wait dutifully until the danger signal was changed to one allowing him to proceed? One smiles at the sight, but underneath the smile is a respect for the obedience to law and the good citizenship which will follow the rule even though there might be the opportunity to make one's own case a plausible exception.

It used to be sufficient for a single officer to guard each corner and handle his problem in his own way. But that day has long passed. In every great city there is increasing group coöperation. Whether our big cities will follow the example of the great thoroughfares of New York and make movement automatic and universal over a large area, time will tell. There is something fascinating about such a system, which moves the traffic forward simultaneously at twenty crossings for so many seconds or minutes, then halts it, then moves it on again.

National automobile associations are endeavoring to introduce uniform signs and signals throughout the country, so that the man who goes from state to state will not have to learn a new set of rules and regulations and follow a new set of signals whenever he has unwittingly crossed a state or county boundary line. The present confusion has come from the suddenness of the problem, as the tremendous increase in the number of automobiles on the road necessitated quick action by local authorities. It will doubtless be soon possible to eliminate the worst difficulties. But the beginning and end of all safety for either automobilist, railroad passenger, or pedestrian is, in spite of all the safety devices which can be invented, in himself.

FIGHTING A LUMBER FIRE

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PUMPING WATER OUT OF THE OCEAN OVER THE EDGE OF A WHARF

THE DEVELOPMENT OF FIRE PROTECTION

FIRE, while one of our greatest necessities, is one of our most terrible enemies when it gets beyond our control. Since its earliest use men have had to take the greatest precautions while employing it in the thousand and one different ways in which it is an absolute necessity, to prevent its destructive power from doing harm.

It is extremely important to extinguish a fire as quickly as possible after it has started. It is far more important to be able to prevent a fire from starting at all. Many inventions have been made with a view to increasing the efficiency of both phases of this problem.

WHEN WAS THE FIRST FIRE DEPARTMENT ORGANIZED?

The first organized fire department of which there is any record was that started in Rome at about the beginning of the first century by the Emperor Augustus. He ordered about seven thousand men to be trained and held in readiness to fight any fire that might occur. No mention is made of their method of fire fighting.

Between this time and the sixteenth century there is apparently no record of fire service, although there is no doubt that citizens banded themselves together in various ways in many places for their mutual protection against this dread element. It is probable that most of this fire fighting was done with water buckets, axes, fire hooks, ladders, and such apparatus.

Between 1300 and 1400 the evidence seems to show that instead of having organized fire companies, every citizen was expected to aid in extinguishing fires, and in some places in England they were expected to keep buckets filled with water ready to be used in case of fire.

EARLY FIRE ENGINES

The time and place of the invention of the fire engine are not known exactly. In chronicles relating to the beginning of the Christian era we find words in the description of the destruction of cities which are translated as meaning "fire engines." The appearance and method of operation of these engines, however, are unknown.

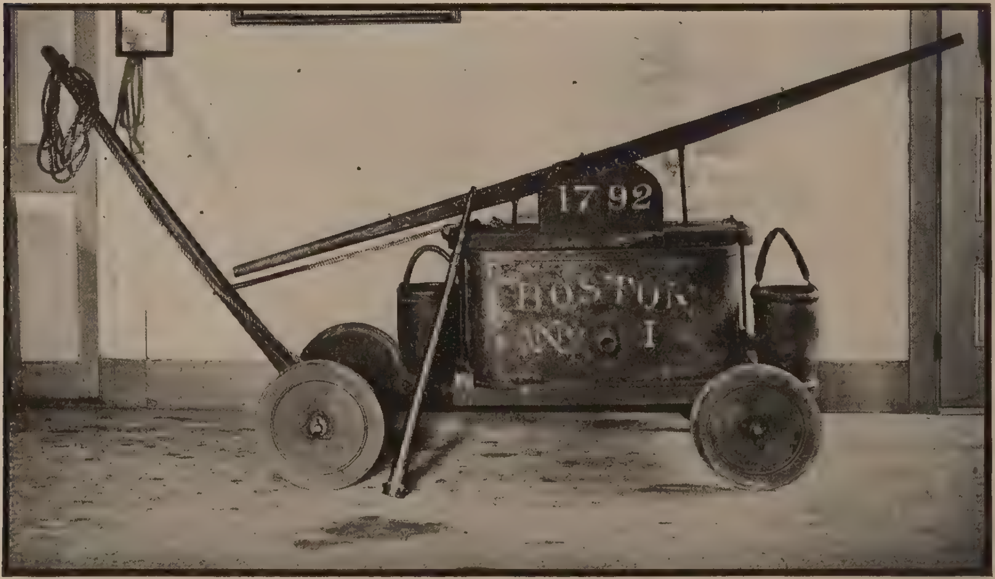
The use of a force pump for extinguishing fire was probably known previous to the eighth or ninth century. Mention is made of fire engines in Germany in the sixteenth century. A fire engine used in Nuremberg in 1657 is described as being ten feet long and four feet wide. It had a water cistern eight feet long, four feet high, and two feet wide. It was worked by twenty-eight men and forced a stream of water one inch in diameter to a height of eighty feet. It stood on a sledge and was drawn by two horses.

The fire engines of the seventeenth century were very imperfect. Owing to their construction they threw water only intermittently, and between strokes the stream ceased entirely. About 1750 the addition of an air chamber on the discharge pipe of the engine overcame this difficulty.

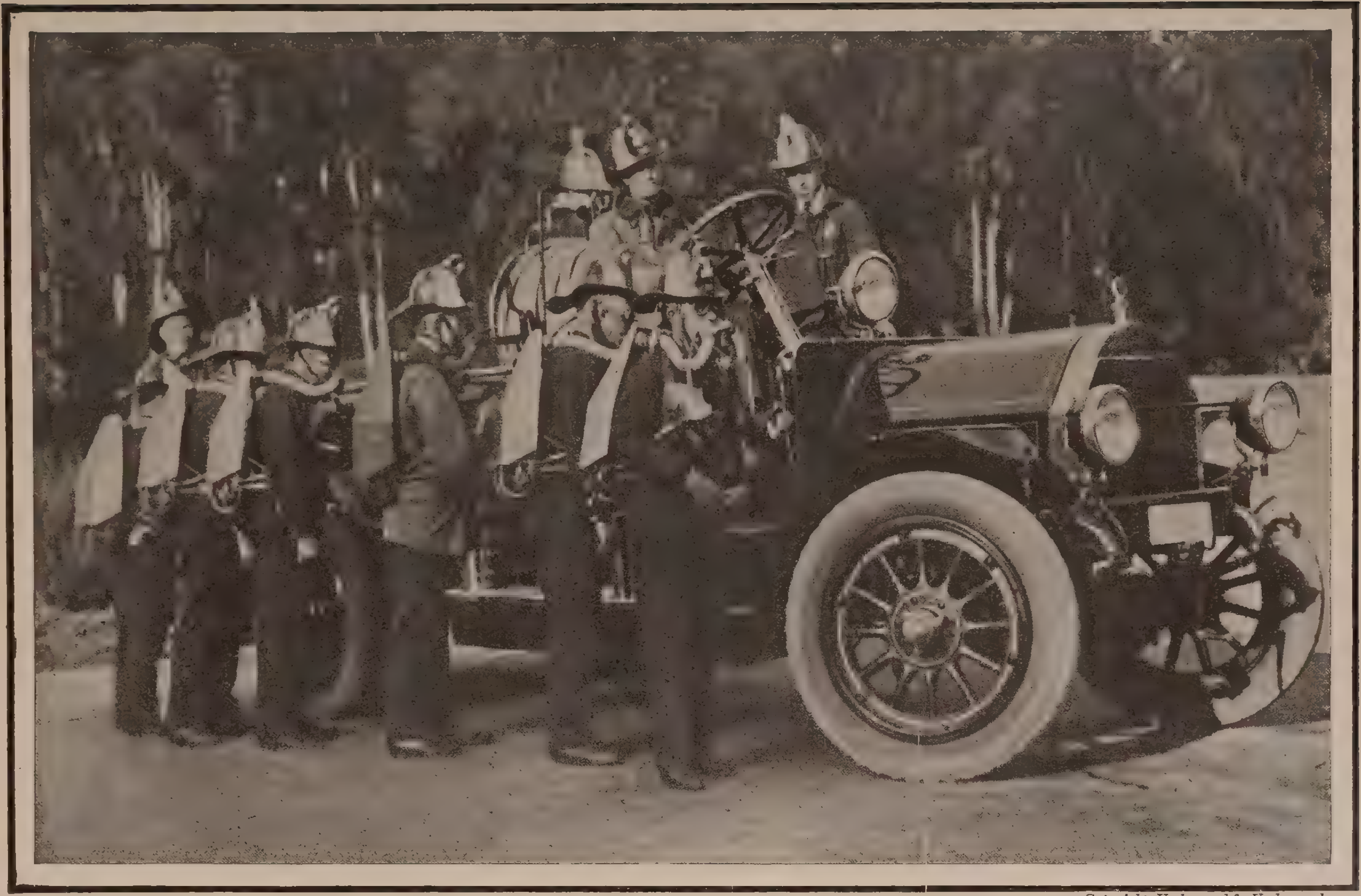
The lack of hose suitable to stand water pressure was a great drawback in the progress of fire fighting. Various materials were tried without success, until in 1672 a leather hose was constructed. This material was used with considerable success for many years. In 1720 hose woven without a seam was made of hemp at Leipsic. This started ideas which eventually produced satisfactory results, especially when canvas, linen, and India rubber came into use as available materials.

The hand fire engines, or hand tubs, as they are now called, have been used in this and many other countries from the earlier times described above down almost to the present, and even to-day many a small country town has its "Columbia" or its "Reliance," which, drawn by all the male inhabitants, dashes to the fire and there, under the combined efforts of fifty men working on the brakes, throws one or more creditable streams of water on the flames.

These engines consisted generally of two or more single-acting plungers of large diameter, and were fitted with large air chambers to



AN OLD-TIME FIRE ENGINE OR HAND TUB



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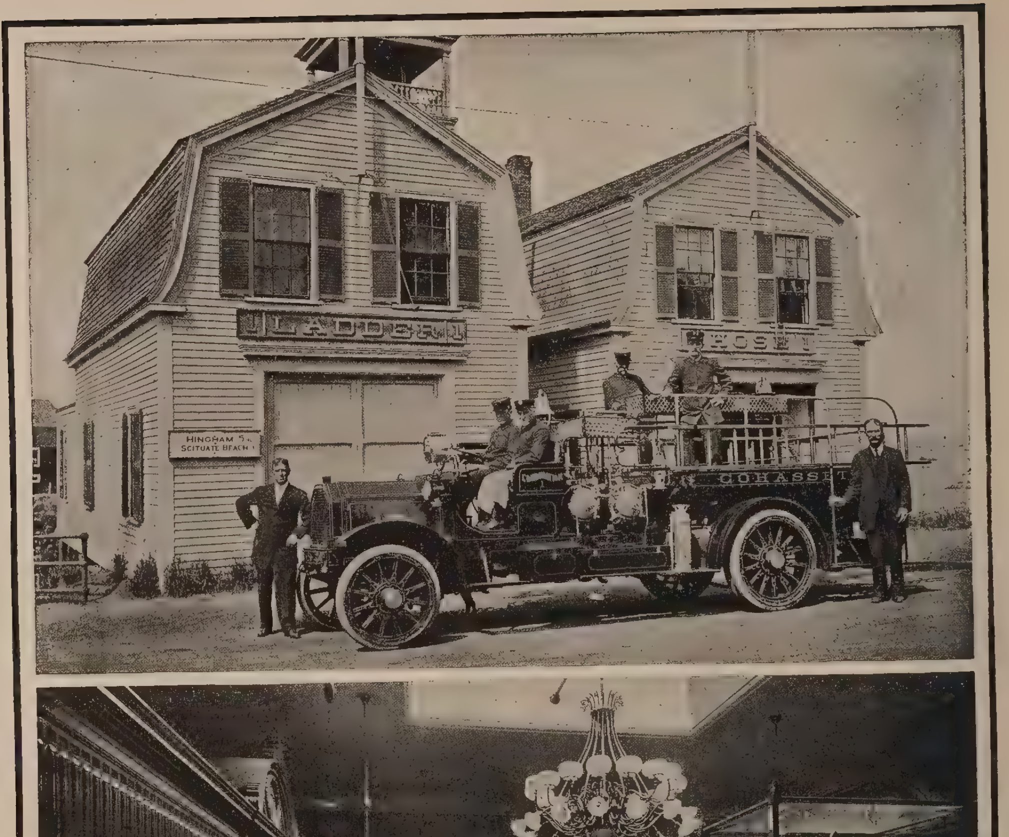
OXYGEN HELMETS WITH GAS MASKS FOR FIREMEN

With oxygen capacity for two hours. Used where smoke or dangerous gas fumes may be encountered, as in mine explosions.


LADDER 1
HOSE 1
HINGHAM S.
SCITUATE BEACH
COHASSET

PARTS OF A MODERN FIRE-FIGHTING SYSTEM

Top: Combination wagon, used in small towns, with chemical, hook and ladder, and hose, all in one. Bottom: Operating room, where electric signals give the location of the fire.

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WHEN THE UNITED STATES TREASURY BUILDING WAS IN DANGER

Ladders and hose are raised mechanically by the engine of the modern truck to heights far beyond the reach of the old-fashioned ladders.

make the discharge continuous. The plungers derived their motion from levers so connected to long handles or brakes that from fifty to seventy men could take hold at once. When working at their best, a stream of water could be thrown a distance of over two hundred feet.

THE APPLICATION OF STEAM POWER

Steam power for driving portable fire-engine pumps was not employed until long after it had been put to this use in factories. The first steam fire engine was built in London in 1829 and was very successful. The first one in America was constructed in 1840, and gradual improvements were added to make the type of steam fire engine which some of our older readers may be able to remember.

With the development of the internal combustion engine, automobile tractors replaced the plunging horses as motive power. Now horse-drawn apparatus is seldom seen except in climates where extreme cold and deep snows render the use of motors impossible in winter months.

Improvements in the efficiency and durability of the gasoline engine led to its use for driving the fire pump as well as supplying the motive power, the same engine serving both purposes. The modern fire engine is a motor pumper capable of throwing hundreds of gallons of water a minute at tremendous pressures.

MODERN FIRE DEPARTMENT APPARATUS

In the modern fire department we find, besides the pumping engine, the ladder truck with its extension ladders, axes, fire hooks, etc.; the aerial ladder, which is a very long ladder that may be mechanically raised from its truck; the water tower, from which a pipe may be elevated one hundred or more feet and a stream of water discharged from it at any angle; the rescue wagon, equipped with devices for saving life; the lighting truck, carrying search lights for the illumination of burning buildings, etc. Chemical tanks, in which carbon dioxide gas is made for extinguishing small fires, are also carried by the pumping engine.

Waterfront cities also operate fire boats, which are speedy boats fitted with powerful fire pumps for fighting fires on ships, docks, etc.

In many large cities a "protective department" is maintained, usually by fire insurance organizations. This company works with the fire department, spreading rubber blankets over goods to prevent water damage, and doing other service for the protection of property during a fire.

The electric fire-alarm system in use in all cities and large towns is no small part of the modern fire-fighting equipment. The ability instantly to report the location of a fire to all the apparatus is a great factor in the extinguishing of a blaze.

The problem of extinguishing fires, particularly in large cities, has of necessity become a science; and the modern fireman is a trained part of a carefully worked out system.

PREVENTIVE MEASURES

So much for stopping a fire after it has started; but it is far better so to construct and act that the fire shall not start at all.

The man to whom, more than anyone else, credit is due for establishing better protection from fires is Edward Atkinson. While from the beginning of the human race some precautions against fire have been taken, it remained for this man to work out ideas and improvements in this line which have made it an applied science or an engineering profession.

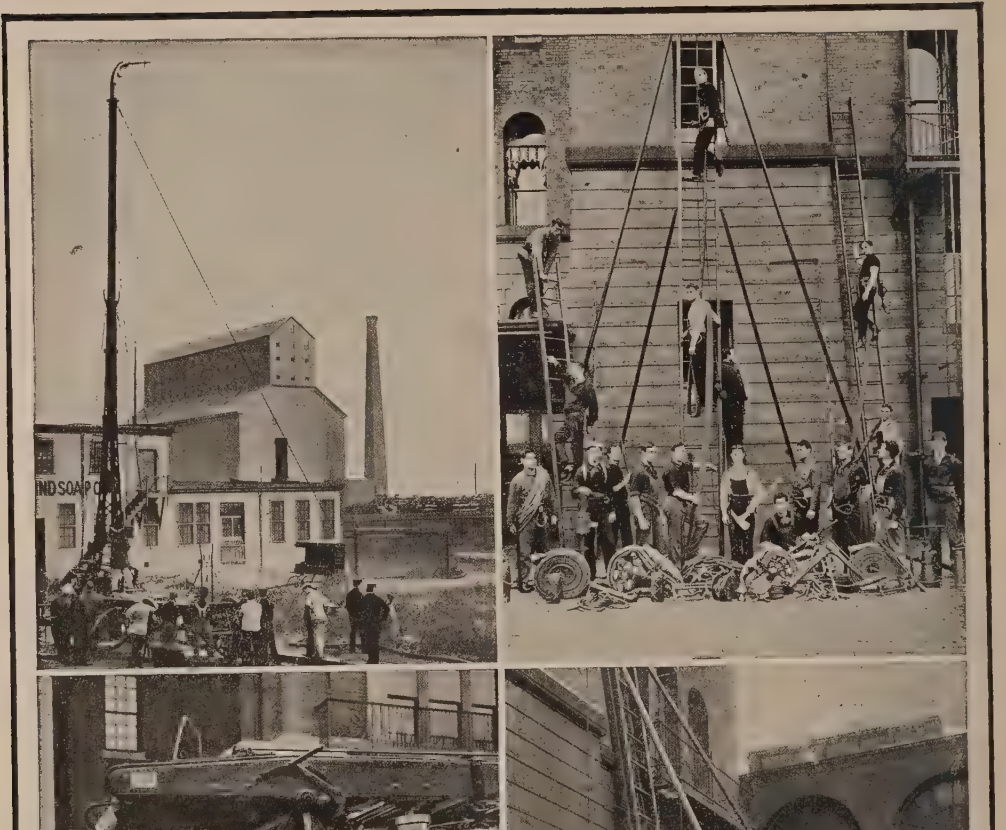
In 1835 one Zachariah Allen, the owner of a cotton mill in Rhode Island, conceived the idea of making his mill safe against fire. He changed the construction, made every improvement, and took every precaution that he could think of. Then he went to the insurance companies and asked for a reduction in his rates. When they refused he decided that it was time to begin a different kind of insurance. The result was the Factory Mutual System of Fire Insurance, which to-day insures two billion dollars' worth of property at very low rates. This system progressed in a very gratifying manner.

James B. Francis of Lowell, our first great hydraulic engineer, was one of those who early saw the possibilities of scientifically protecting buildings from fire. He did much toward this end.

Photo, Ewing Galloway

FIGHTING A FIRE FROM ABOVE

Firemen have torn up the roof of this building to drown a fire on the top floor. Good water pressure is indispensable in fire fighting.



THE WATER TOWER AND AËRIAL LADDER

Top: Practicing on water tower and ladders at drill school. Bottom: Compressed air hoist for an aërial ladder. Raising an extension ladder.

In 1877 Edward Atkinson became president of the Factory Mutual System, and it is to his ingenuity and foresight that we owe much of what is now the best common practice in fire prevention. He began by studying the common causes of fire, and then set about to apply remedies. Then he sought and perfected devices to extinguish and retard fire. The most important of these were the automatic sprinkler, the fire door, the standpipe and hose, and the fire pump.

SLOW-BURNING AND FIREPROOF CONSTRUCTION

One of his valuable schemes was the so-called "slow-burning" or "mill" construction. This is simply a building having the best plank and timber in its internal make-up. The posts, beams, and girders are twelve inches square, and the flooring is of four-inch planks laid directly on the timbers. It is almost impossible for fire to burn through this construction when the work is well done. The dangerous parts of such a building, vertical openings for stairs, elevators, etc., are placed in brick towers outside the building proper. This type of building is one of the safest known to-day.

The modern "fireproof" buildings are, however, in general built with a structural steel framework and a brick, stone, or concrete exterior. The very latest type of fireproof building is constructed almost wholly of concrete. Beams, girders, floors, posts, walls, and even roofs are built of this wonderful material. When, as is the case in all places where heavy loads are to be carried, the concrete is strengthened by steel or iron rods in its interior, it is called "reënforced" concrete.

Atkinson, in taking every precaution possible against fire, added fire doors and fire windows to his buildings. The first was a heavy wooden door covered on all sides with roofing tin (this construction giving better results than an iron or steel door), so arranged on an inclined track that it could be instantly and automatically closed in case of fire. The door was automatically closed when a fusible metal which held it open was melted by the heat of the fire, the melting temperature being about 155 degrees Fahrenheit. In this way necessary openings in fireproof walls were effectually closed.

Shutters of the same construction were fitted to the windows and could be closed in case of fire. Later wire-glass windows were used almost exclusively. These were made of heavy glass containing wire netting in its construction, so that if the glass were cracked by heat, the window would still remain intact. The frame was, of course, of steel construction.

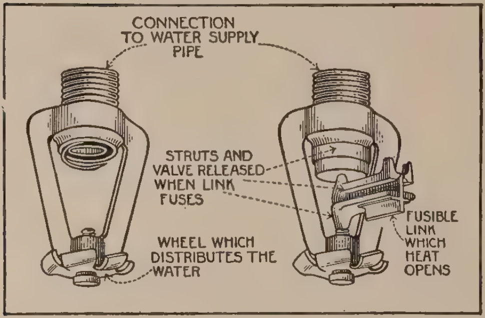
The problem of theater construction is a very serious one, as many terrible conflagrations have occurred in these places of amusement. The modern theater is usually of the reënforced concrete or of the structural steel and concrete construction. The proscenium wall, which is that separating the stage from the auditorium, is of brick or reënforced concrete, and all openings may be instantly closed with fire doors. The proscenium arch, through which the stage is seen, may be as promptly closed by an asbestos or an iron curtain. The roof above the stage is almost entirely of glass, which may be almost instantly removed from below, so that any smoke and flames may be drawn upward and not pass out into the auditorium. In some theaters there is an arrangement by which a curtain made of a solid sheet of water may be interposed between the audience and the stage.

Many large buildings of the present time are constructed so that a solid curtain of water like that just described may be dropped on all sides, thus forming an efficient protection from fires in adjoining buildings.

FIRE EXTINGUISHERS

The first fire extinguisher was a pail of water, and for most fires, if taken at the beginning, there is nothing better to-day. It is the custom in many buildings to have pails of water placed at advantageous points and marked "For Fire Only."

Among the many modern devices for extinguishing fires the automatic sprinkler is one of the most effective. It is now used in all mills and practically all large department stores and manufacturing establishments. The sprinkler itself, one form of which is shown here, is really a water faucet kept shut by


CONNECTION TO WATER SUPPLY PIPE
STRUTS AND VALVE RELEASED WHEN LINK FUSES
WHEEL WHICH DISTRIBUTES THE WATER
FUSIBLE LINK WHICH HEAT OPENS

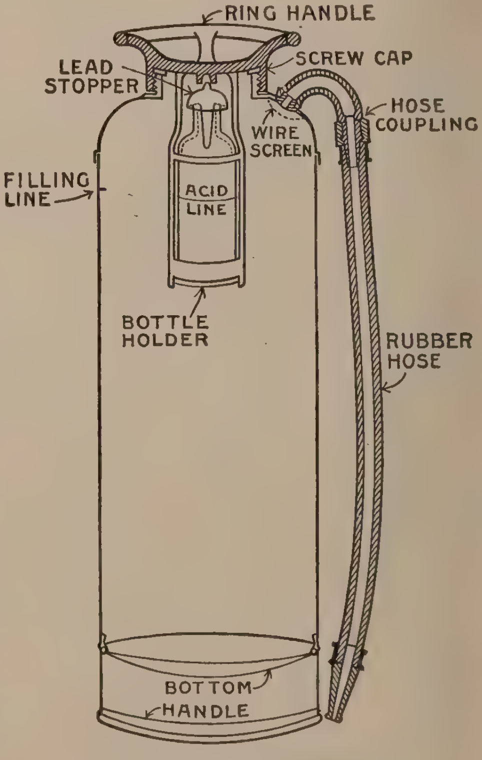
THE AUTOMATIC SPRINKLER

a lever held by a fusible metal melting at about 155 degrees Fahrenheit. When this melts the lever drops and the water is automatically turned on. The outlet is so arranged that when the sprinkler is set in a ceiling it will cover a floor space about ten feet in diameter. These are generally placed at eight-foot intervals all over the ceiling of a room, so that the whole room or any part may be covered with water upon the temperature at the sprinkler rising to 155 degrees. In the latest systems, not only does the sprinkler pour water on the fire, but an alarm is instantly sent to a central station showing the exact location of the fire.

One object of pouring water on fire is to smother the flames or to prevent oxygen from being supplied. The same object may be accomplished with less damage to surrounding objects, if the fire is small, by covering the flames with carbonic acid gas. This, for the larger fires, is supplied by the chemical fire engine. The chemical hand fire extinguisher furnishes the same gas on a small scale. A common form is shown in the illustration. This consists of a copper tank containing a solution of bicarbonate of soda and water up to the "filling line." In the bottle holder is a glass bottle half full of sulphuric acid. This bottle has a lead stopper fitting loosely in the top. The bottle holder is fastened to the cap, which is screwed on, making a water-tight joint. A hose is connected as shown. In its upright position no action takes place, as the soda solution and the acid are each in their own receptacles. When the tank is inverted, however, the stopper opens the bottle very slightly, allowing the acid and the soda slowly to mix. This combination forms carbonic acid gas, which passes off through the hose with sufficient pressure to be discharged with great force. The extinguisher, when not in use, is simply hung in an upright position. In case of fire it is held on one arm or set down in an inverted position, and the gas issuing from the hose is directed on the flames.

FIRE PUMPS

Another appliance for fire fighting found in all large manufacturing establishments is the fire standpipe with its connections. This usually consists of a large tank, generally situated on the roof of the building and holding a number of thousand gallons of water. From this tank a pipe descends through the building, with one or more hose connections on each floor. The tank must be kept full of water, and in



A CHEMICAL FIRE EXTINGUISHER

Copyright, International

A MODERN FIRE-FIGHTING MACHINE

In which a centrifugal pump driven by the same gasoline that moves the apparatus delivers several streams of water at 300 pounds pressure.

case of fire must be supplied by a pump instantly available for that purpose.

The modern fire pump, which is the result of the designing of John R. Freeman and F. L. Pierce, is called the "underwriters' standard." It is a direct-acting, duplex steam pump designed to pump large quantities of water against high pressures. It is almost universally used to-day where permanent fire pumps are installed.

WATCHMEN AND SIGNAL SYSTEMS

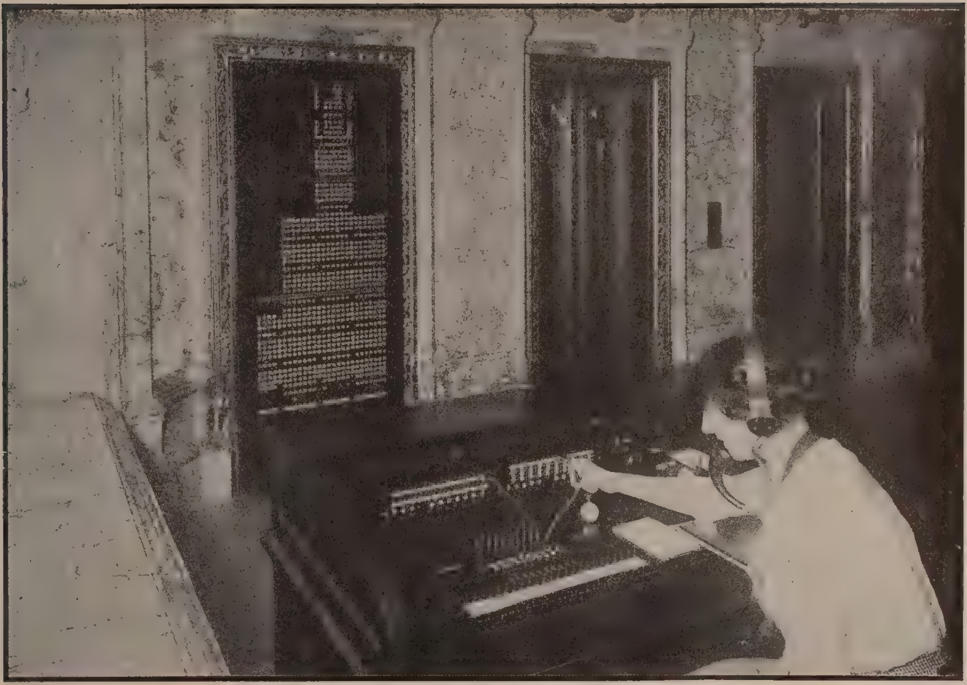
In all large establishments it is the custom to employ one or more men to patrol the buildings during the night to see that all is well. In order to be sure that the work is conscientiously done, various systems have been devised by which the watchman on his rounds registers at frequent intervals his presence at different points. This information is electrically transmitted to a central point, where a record is automatically made showing the time and place of the register.

Various systems have also been devised where, by a rise in temperature due to a fire, a signal is carried to a watched station showing the location of such a fire.

Thus we see that while the danger of fire increases with the increase of population, yet with the many precautions which are taken and the many devices which are available, we are really safer to-day from destructive fires than we have been in the past.

FIRE BOATS

Fires occurring on or near water are now handled efficiently by fire boats, which are large, fast tugs containing powerful fire pumps.



GIRL ELEVATOR CONTROLLER IN THE WOOLWORTH BUILDING

The position of each elevator in this great building is shown by an indicator on the board, whose outline is that of the building. By telephone connection the controller can communicate with any car and thus manage the whole system.

ELEVATORS AND THEIR OPERATION

SO long as buildings were not more than two stories in height, it was unnecessary to have any other means than stairways for passing from one story to another. With the present-day structures, however, some of them over fifty stories high, if stairs only were available a man would spend the most of his time on these stairs going up and down. The invention of the elevator has been, therefore, of great importance, and its perfection one of the factors which has made the building of the modern skyscraper possible.

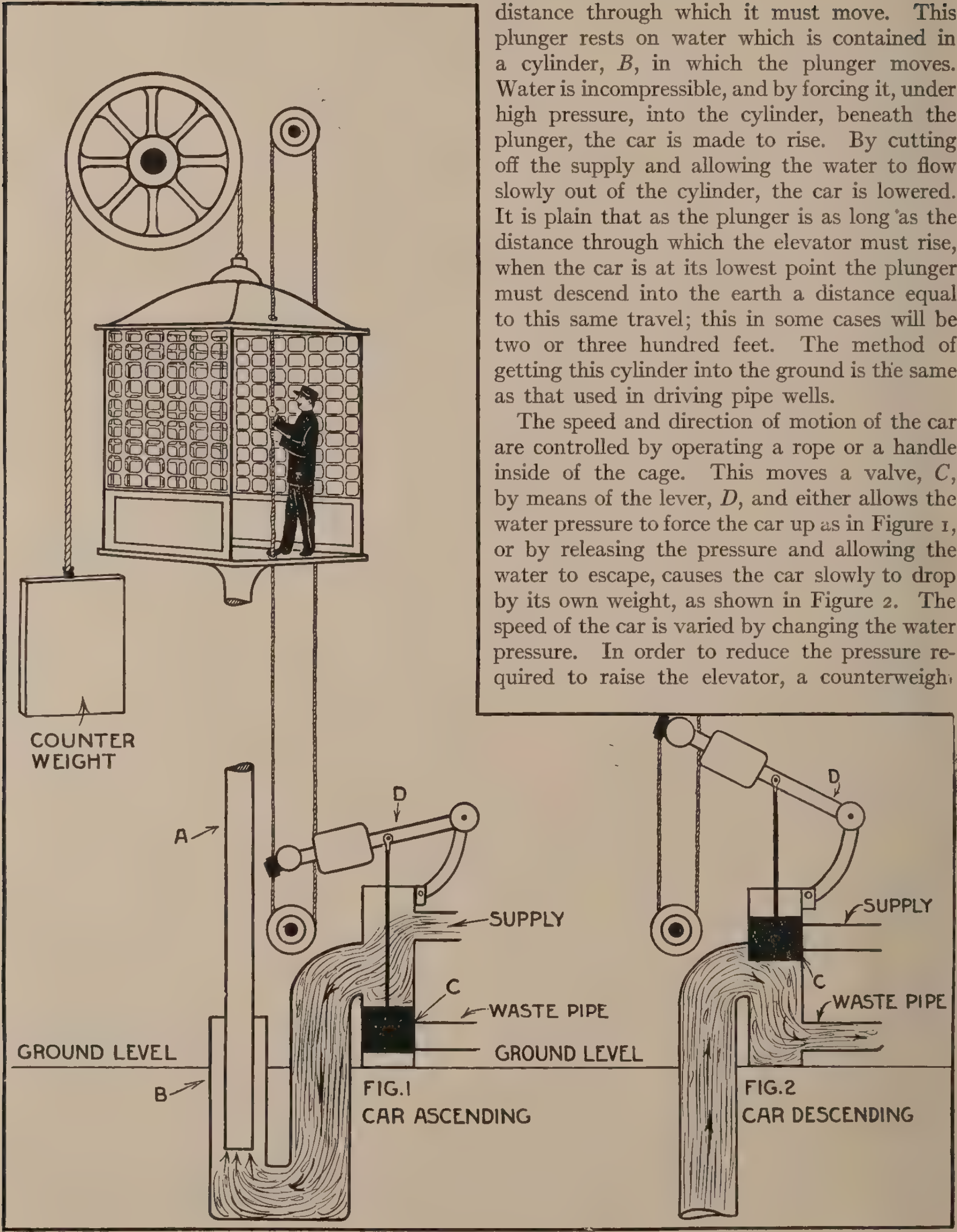
THE FIRST ELEVATORS

There seems to be no record of the specific invention of the elevator. It was used naturally in crude ways by ingenious persons many years ago. The first mention we find of its being manufactured for general use is in 1850, when G. H. Fox & Co. built an elevator for commercial purposes which could be adapted for either passengers or freight. This was operated by the turning of a vertical screw with the elevator car fastened to what would correspond to the nut, so that the rotation of the screw caused the car to ascend or descend according to the direction of turning. This machine was used for about twenty years with considerable success, when it was replaced by the hydraulic plunger type.

THE HYDRAULIC PLUNGER ELEVATOR

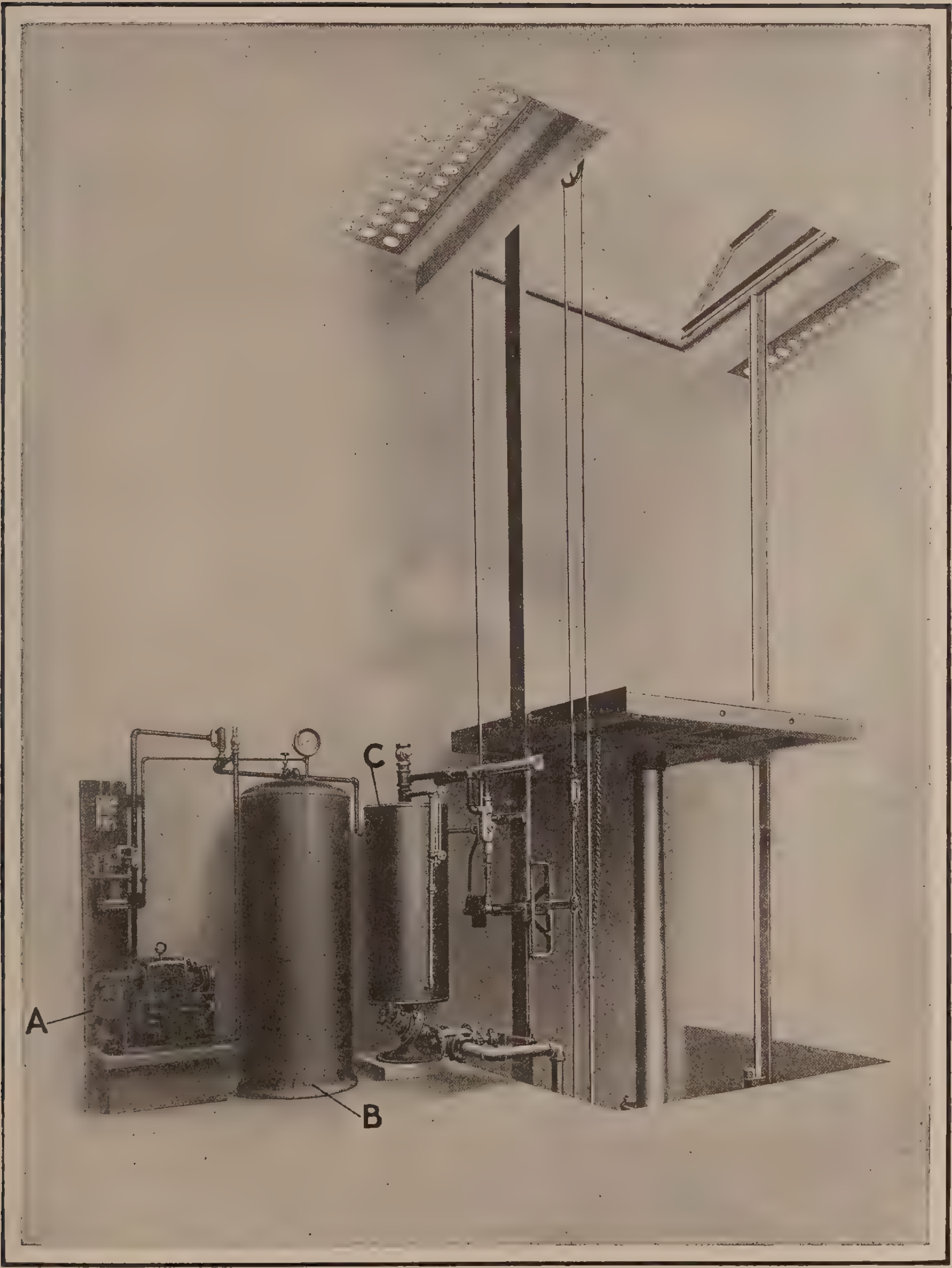
The action of this type of elevator is shown on the following page. The elevator car is supported on a hollow steel plunger, *A*, the length of which is a number of feet greater than the distance through which it must move. This plunger rests on water which is contained in a cylinder, *B*, in which the plunger moves. Water is incompressible, and by forcing it, under high pressure, into the cylinder, beneath the plunger, the car is made to rise. By cutting off the supply and allowing the water to flow slowly out of the cylinder, the car is lowered. It is plain that as the plunger is as long as the distance through which the elevator must rise, when the car is at its lowest point the plunger must descend into the earth a distance equal to this same travel; this in some cases will be two or three hundred feet. The method of getting this cylinder into the ground is the same as that used in driving pipe wells.

The speed and direction of motion of the car are controlled by operating a rope or a handle inside of the cage. This moves a valve, *C*, by means of the lever, *D*, and either allows the water pressure to force the car up as in Figure 1, or by releasing the pressure and allowing the water to escape, causes the car slowly to drop by its own weight, as shown in Figure 2. The speed of the car is varied by changing the water pressure. In order to reduce the pressure required to raise the elevator, a counterweigh



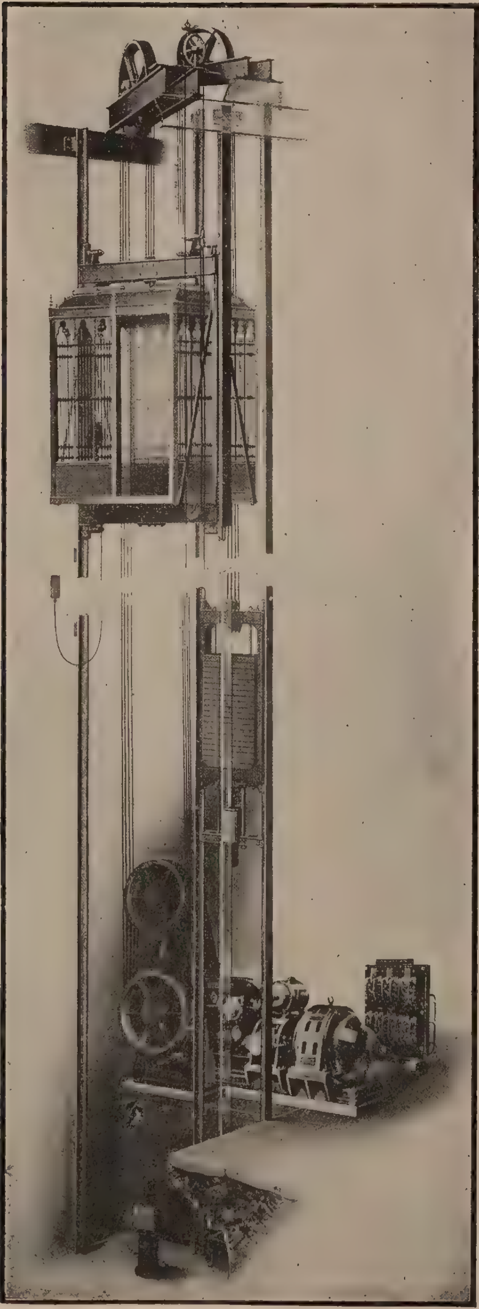
HOW A HYDRAULIC ELEVATOR WORKS

The man in the cage pulls the rope and lets the water rush in, forcing the car up, or escape, allowing the car to drop by its own weight.



THE PLUNGER TYPE OF HYDRAULIC SIDEWALK ELEVATOR

An electrically driven air compressor, *A*, forces the air into a main storage tank, *B*, from which it passes to force up water through a tank, *C*, into the plunger cylinder.



AN ELECTRIC ELEVATOR

is provided. The water pressure for operating such elevators is supplied by a pump especially designed for such high-pressure service. It is usually a direct-acting steam pump.

This type of elevator is in use to-day in many places. It has, of course, been improved in many ways, but the general method of operation remains the same. On the previous page is shown the machinery of the plunger type of hydraulic sidewalk elevator. The general features of this machine are similar to that previously described, except that the water pressure is here obtained by compressed air. This is supplied by an electrically driven air compressor, *A*, which forces the air into the main storage tank, *B*, from which it passes, when the operator moves the control, to an auxiliary tank, *C*, which is three quarters full of water and from which the compressed air forces this water into the plunger cylinder.

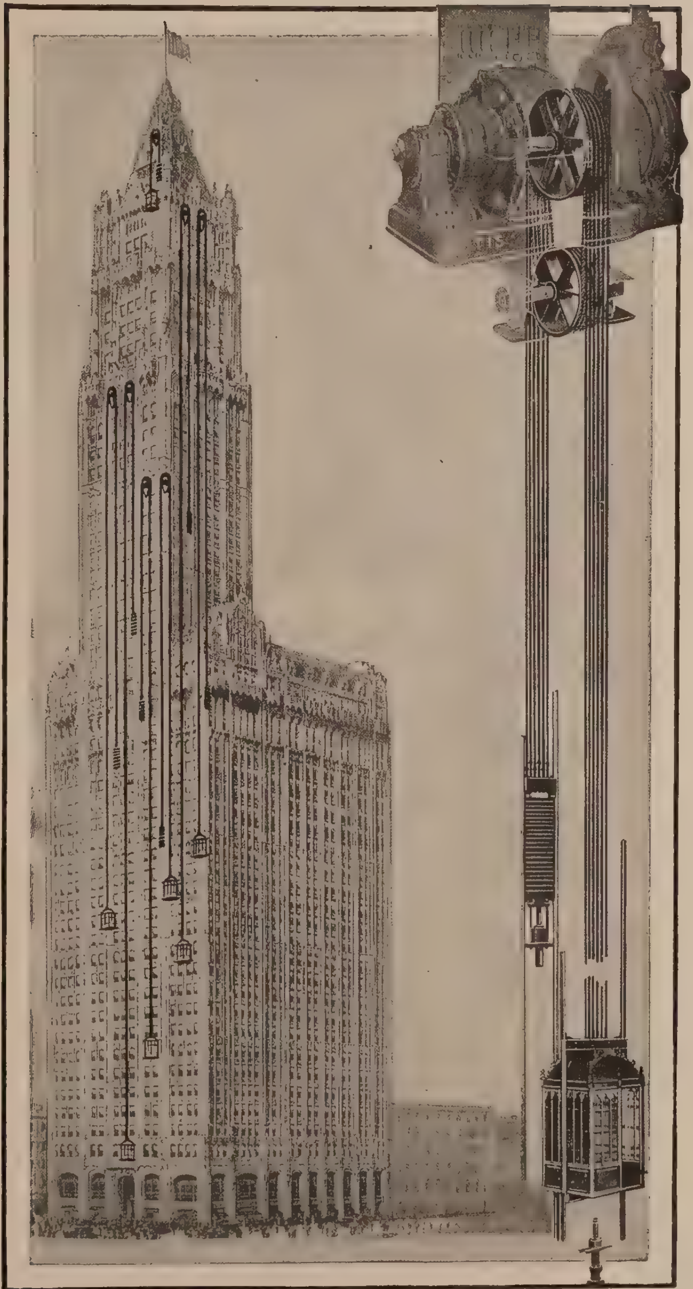
ELECTRIC ELEVATORS

When the electric motor became a success, it was applied to elevator service and made an excellent drive, as the starting, stopping, and speed of the motor could easily be controlled from inside the car.

One common type of electric elevator with the motor at the lower end is shown here. The method of hoisting by ropes passing over sheaves is plainly indicated. The speed of the motor is reduced by worm gears so as to cause the car to move at the proper rate. Variation in speed is obtained by changing the worm-gear ratios. This is all operated by a master switch in the car. As these electric elevators are run at high speeds, some form of automatic retarding device is necessary. One of these is composed of two groups of switches located respectively at the top and bottom of the shaft, each switch in the group being thrown out, one after the other, as the car passes, resulting in a gradual reduction of the speed until the car stops as the final switch is opened. This operation is entirely independent of the operator in the car. A counterweight is here used, as in the previously described type, to lessen the work of the motor in raising the car.

The next illustration (page 209) shows the Woolworth Building in New York City with the type of elevator system there used. This system is very similar to that just described, except that the motor is located at the top.

The travel of the elevators as indicated on the building is intended to represent the different groups in use. It will be seen that several of the elevators travel in one continuous hatchway from the lower level to within two or three floors of the top of the tower, which is fifty-seven stories above the street level. From the point where these elevators stop there is installed a shuttle car running to the top of the tower, the reason for this being to facilitate the arrangement of the elevators traveling to the lower floors. The large number of elevators in use in this building has made necessary a special system of control. Each elevator is connected by telephone with the controller and with an indicator which shows the person in charge of the control the position of each car. This system of indicators can be seen in the picture at the beginning of the chapter (page 205), in the left-hand doorway space. Its outline is the same as that of the building. As the cars pass up and down little glow lamps show their varying positions so that the controller knows the exact position of each elevator. Communication



THE ELEVATOR SYSTEM OF THE WOOLWORTH BUILDING, NEW YORK can be instantly established with any car by telephone, and the operation of the whole system is virtually under the control of one person who acts as a sort of train dispatcher, keeping everything in smooth running order.

AUTOMATIC ELEVATORS

One system which does away with the necessity of having an attendant in the car is the automatic elevator. With this system the elevator may be brought to any floor by the pressure of a button. A person riding in the car may stop at his destination by pressing the proper one of a series of buttons.

An interesting system where no elevator boys are needed, in use in some of the office buildings in Germany, is one constructed like an endless conveyor used for hoisting coal, earth, or similar material. It consists of a series of cars or cages arranged on an endless belt which has a slow motion over two sets of sprockets, one at either end, traveling from the bottom of a building to the top and back again. These cars move slowly by open doors on each floor. If a person on the first floor wishes to travel to the top of the building, he waits until an empty cage gets opposite the first-floor door and steps in; he is then lifted slowly, and when he reaches the proper floor he steps out. The string of cars is, of course, in continuous motion. The cage then passes up over the top of its travel and descends past another series of doors on each floor.

THE ESCALATOR OR MOVING STAIRCASE

Another system of recent invention used for short lifts is the so-called escalator or moving staircase. These in general are of two kinds. One is constructed like a treadmill, with wooden slats arranged on an endless-chain belt running over sprockets, one at the top and one at the bottom. The belt is set at about the same angle as a flight of stairs, so that a person, by grasping moving rails one on each side and standing on the slats, will be lifted much faster and more conveniently than he could walk. If he so desires he can walk up the treadmill while it is moving, thus increasing his rate of motion.

The most modern escalator, however, is literally a moving staircase. Treads and risers like those on ordinary stairs are arranged on the moving chain and have the appearance of an ordinary flight of stairs in motion. One may stand on a stair and rise to the top, or may walk up the stairs as they move. When the top is reached, each stair disappears under the floor and returns to the bottom for another load. This kind of escalator is often used in department stores, hotels, and similar places.

SAFETY APPLIANCES

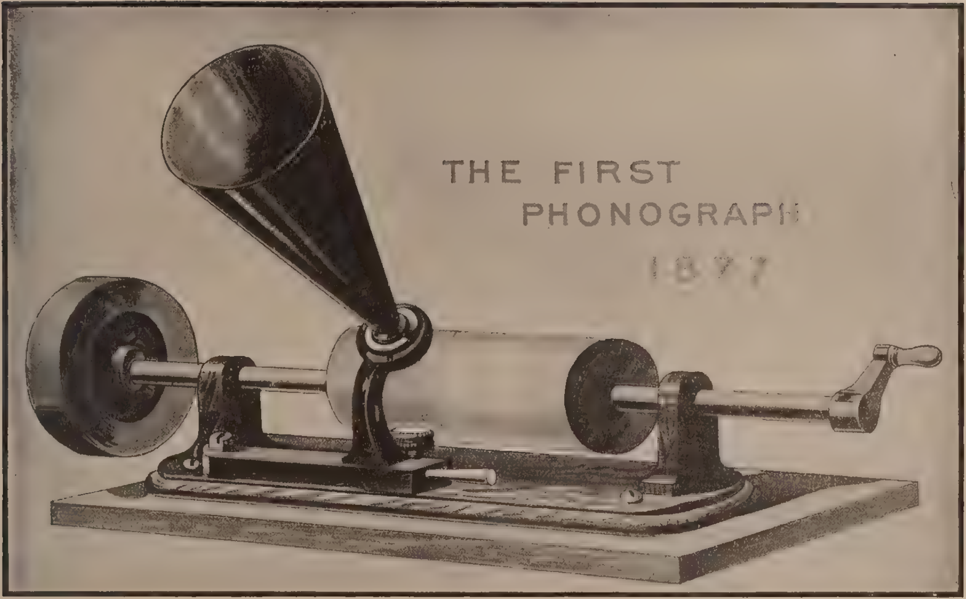
Owing to the possibility of serious accidents on all elevator systems, numerous different safety appliances have been devised; and in many cases several devices are used on the same system to make safe travel doubly certain. These appliances work in a variety of ways. An air cushion is sometimes provided at the bottom of the elevator shaft to lessen the shock in case a car falls. The depth of this cushion is made one tenth the depth of the shaft. Another arrangement, for safety, is the sliding, automatically closing door leading to the elevator well on each floor.

Many appliances work as grips and brakes, to act if the speed of the car becomes too great, slowing it down by friction against the cables, the plunger, or the sides of the car. Safety governors are often used which cause retarding devices to act if the speed becomes dangerous.

ENDLESS CHAIN CONVEYORS

The hoists or conveyors mentioned above in connection with escalators are in common use in many places for raising large quantities of material through short distances. In general they are a series of buckets arranged on an endless chain. These buckets dip into the material at the bottom, carry it to the top, and dump it as they are turned upside down by the motion of the chain. These conveyors are very important as labor-saving devices.

The whole question of traveling by elevators has now reached such a high state of perfection that one may ride with speed and with practically perfect safety from the street level to a floor fifty stories in the air.



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THE PHONOGRAPH AND ITS INVENTOR

AMONG the many brilliant ideas which have sprung from the marvelous mind of the wizard Edison, few have produced a more lasting impression on the world at large than that which made the modern talking machine possible.

The first phonograph appeared in 1876, but as early as 1856 an instrument was devised by a man named Scott which would mechanically register the atmospheric vibrations caused by the human voice or by musical instruments. This, however, was only a recorder, not a reproducer, and this second part did not make its appearance until Edison embodied both principles in his first phonograph. It was a very simple instrument and consisted of a metal cylinder finely threaded with a continuous square-section groove. This was mounted on a long spindle supported on upright bearings and having at one end a screw thread with the same pitch as that cut on the cylinder. A heavy flywheel was also placed on the spindle to make the speed of rotation uniform, and the whole was turned by a handle. A thin sheet of tin foil was stretched over the grooved cylinder and on it rested a steel point held down by a spring and separated from a vibrating diaphragm by a rubber pad. There was also a large mouthpiece to concentrate the sound vibrations.

To make a record with this machine a person would speak into the mouthpiece, turning the spindle by hand at the same time. The vibrations set up by the voice acted through the diaphragm on the steel needle and caused its movements to correspond with these voice vibrations. Then the needle, passing over the tin foil directly above the grooves in the cylinder, forced the thin sheet down into the grooves to a greater or less degree according to the vibrations. When the record was completed the needle could be again started in the grooves it had just made in the tin foil and the variation in the shape and depth of the grooves caused by the different vibrations of the voice would reproduce the sounds which had caused the vibrations. This first instrument, of course, had many faults. It was heavy, clumsy, and harsh-toned, and the records became quickly worn out.

After getting out this machine Edison did no work on the phonograph for some years, his time being occupied with the telephone and electric lamps. During this time two brothers, Graham and Chichester Bell, and one Charles Taintor developed and improved the ideas started by Edison. A thin wax coating on a paper cylinder was substituted for the tin foil, and the spindle was turned by a clock-spring-driven motor instead of by hand.

When Edison again turned his attention to the phonograph, he introduced an all-wax cylinder and invented a machine by means of which the surface of a worn record could be shaved off and a new record made on the fresh surface.

In making a record for the modern phonograph or graphophone, the cutting is done by a very small sapphire point having a circular concave end with very sharp edges. This point gouges minute depressions into the wax. The vibrational movement of this point is caused by a diaphragm made of French glass, $1\frac{1}{40}$ inch thick, which is connected with the sapphire point by a delicate series of weights and levers.

The reproducing is accomplished by a sapphire ball with the same diameter as that of the gouge. This process is simply a reversal of that used in making the record, and its delicacy is such that a record may be used one hundred times with apparently no wearing effect.

It is interesting to notice that the reproducing parts of a phonograph have functions exactly corresponding to those possessed by the bones in the ear called the "hammer," "anvil," and "stirrup."

RECORD MAKING

Phonograph records are made in two shapes, cylindrical and flat. The cylindrical records are generally of wax and the flat of vulcanite or celluloid. The latter are cut with a continuous volute groove starting at the edge of the disk and ending at the center. These flat records are used for reproducing only. Their process of manufacture is as follows: The record is first made on a sheet of zinc coated with a very thin film of wax. The recording needle resting on this wax removes portions of it as the vibrations agitate the needle. This uncovers the zinc underneath. By flooding the plate with an acid the bare places are etched while the portion covered with wax is not affected. The wax is then removed and an electrotype negative of the record is the result.

The celluloid or vulcanite records are then made from this "master" record by bringing the two into contact under heavy pressure.

Two processes may be used in making cylindrical wax records, copying, and molding. In copying, the master record and a blank cylinder are mounted side by side on the same spindle. A reproducing point which passes over the master cylinder is connected by levers with a cutting point, which passes over and cuts the blank cylinder exactly as the reproducer moves over the master record. The result is an exact duplicate of this record. This process is, however, necessarily slow and most records are made by the molding process.

Edison's inventive genius was here shown again when he found that by inclosing a wax record in a vacuum between two gold electrodes he was able to coat the record with a very thin film of pure gold on which silver or nickel could easily be deposited. This deposit was made sufficiently heavy so that the wax could be melted out, leaving an electrotype negative from which cylindrical wax records could be made, the cooling of the wax causing enough shrinkage to allow for the removing of the molded records.

While at present the phonograph has its greatest use as an entertainer, yet its practical value is continually being demonstrated along many lines. It is used in offices for repeating dictation to a stenographer, in the Canadian Parliament for recording parliamentary proceedings, as a teacher, particularly in instructing in the foreign languages, and in many other similar ways.

EDISON AND HIS INVENTIONS

As the name of Edison is mentioned here in connection with the invention of the phonograph, a suitable opportunity is offered for giving a brief sketch of the career of this great inventor and mentioning a few of the many other devices which he has invented or helped to bring to perfection and into practical use.

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THOMAS ALVA EDISON

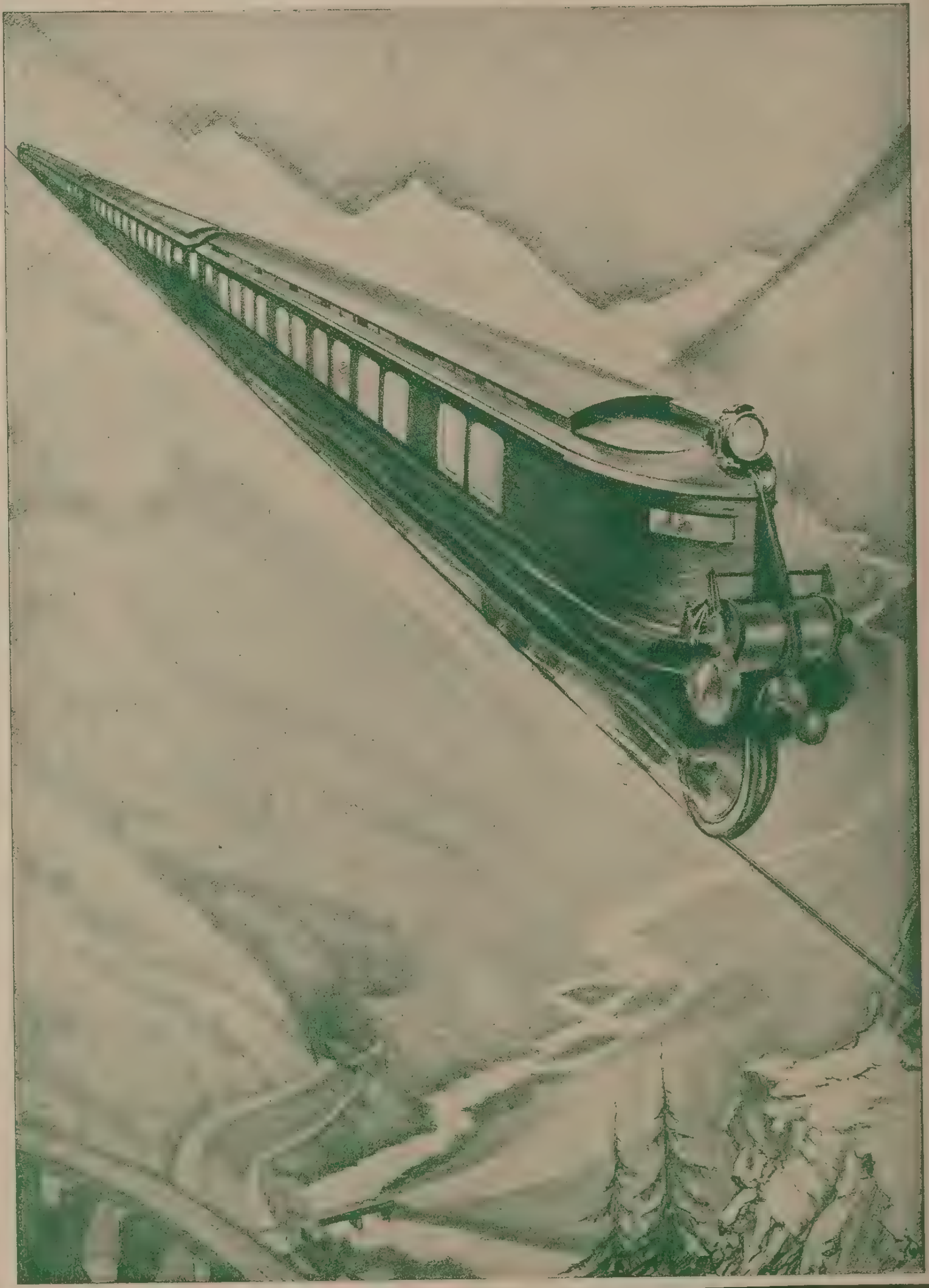
Edison was born at Milan, Ohio, in 1847. His family moved to Port Huron, Mich., when the boy was seven years old, and it was on the Detroit and Port Huron branch of the Grand Trunk Railway that, at the age of twelve, he became a train boy. His only schooling, meanwhile, had been such as he was given at home.

In a short time an opportunity came to him to learn telegraphy, and while only a boy he was installed as operator at Mount Clemens, Mich. At the telegraph key he was unusually expert, and in his later wanderings as a so-called "tramp operator" Edison was always sure of a position. While temporarily engaged in Indianapolis, at the age of seventeen, he made his first invention, an automatic telegraph repeater. A little later, while employed in Boston, he invented a commercial stock indicator, and this device he soon sold to New York capitalists for forty thousand dollars. With the money thus obtained Edison built a laboratory at Newark, N. J., for the manufacture of electrical, printing, and other apparatus.

In this Newark laboratory and later ones at Menlo Park and West Orange, N. J., Edison studied out the long series of devices that have worked such changes in our modern world. One of the most notable of these is the incandescent electric lamp. To discover the carbon filament for this light required weeks of persistent experimenting and almost ceaseless labor. Others of his leading inventions are the carbon telephone transmitter, a storage battery for street railway cars and automobiles, multiple systems of telegraphy—duplex, quadruplex, and finally sextuplex—and the kinetoscope. Every electrical instrument and electrical process now in use bears the mark of some great change wrought by this leader among the inventive geniuses of the world. Over three hundred patents have been issued on his inventions, in addition to which he has made numerous minor improvements not covered by patents.

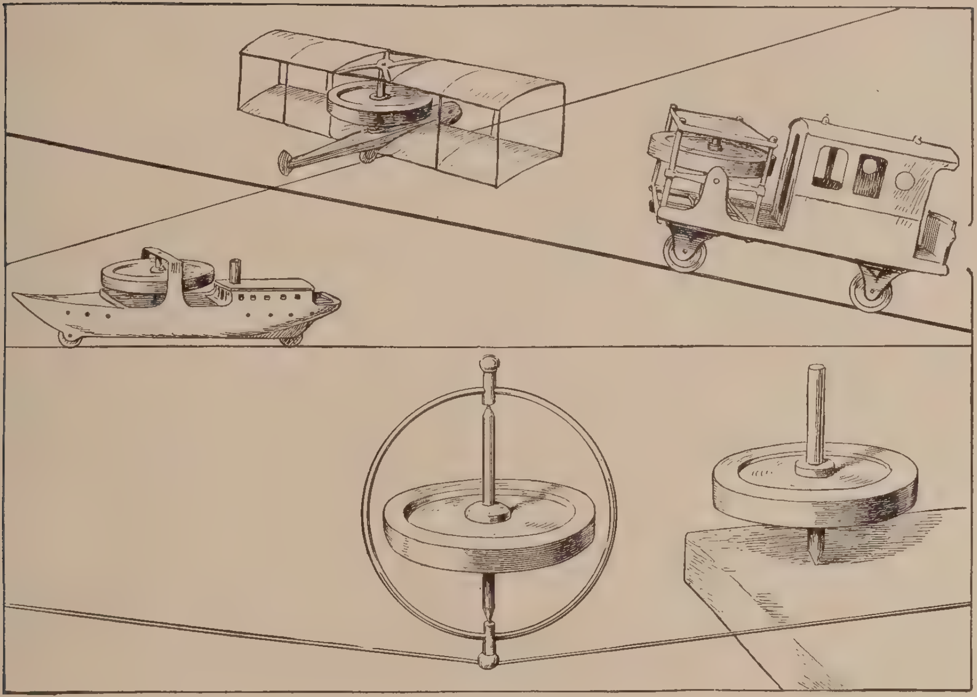
EDISON'S BIRTHPLACE

A TRAIN BALANCED ON A SINGLE RAIL



GYROSCOPES SPINNING LIKE A CHILD'S TOP KEEP IT UPRIGHT

The marvelous gyroscope, used to stabilize or keep level trains, ships, airplanes, and torpedoes, works on the principle of a spinning top. A top will keep on spinning at the same angle, the same "tip," at which it was started and will resist any attempt to change its "tip." The pull of gyroscopes spinning inside this train, each trying to keep its own angle, is strong enough to keep the whole train steady.



THE GYROSCOPE IN ACTION

In each toy may be seen the gyroscope top which preserves the balance of the machine.

SOME OF THE NEWER INVENTIONS

THE GYROSCOPE

THE gyroscope has long been one of the most marvelous of scientific toys, apparently disobeying all the laws of mechanics with which we are familiar. Until recently it has been little more than a toy, although many attempts have been made to apply it to practical uses. In the last few years, however, inventors have succeeded in overcoming many of the technical difficulties which accompany its use, so that now it is being successfully used for many purposes astounding to the uninitiated.

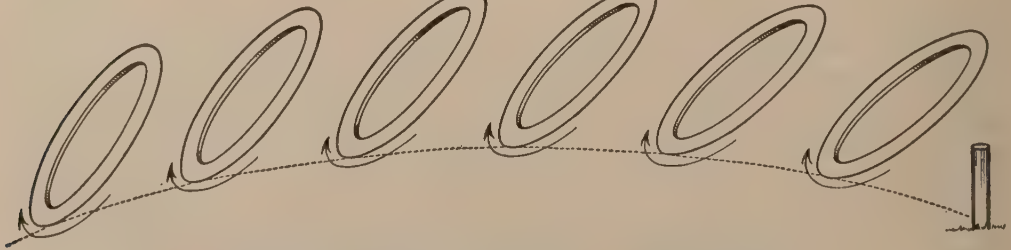
What a gyroscope is, is familiar to anyone acquainted with the toy gyroscope frequently sold by the fakirs at Christmas time. It consists essentially of a heavy wheel rotating with little friction on an axle which is so mounted in a system of rings that it is free to turn in any direction. Such a wheel, when rotating at a high speed, will perform many surprising antics, such as running down a stretched string without falling over. Completely to understand why a gyroscope acts as it does would demand familiarity with much complicated mathematics, and cannot be attempted here. What we can do, however, is to describe how a gyroscope may be expected to act in certain simple cases.

The fundamental principle of the gyroscope is a simple one, familiar to all of us. It is that when a body is rotating about an axis it tends to keep on rotating about the same axis, and that it takes some force to make it rotate about a different axis, or to change the direction of the axis about which it started to rotate. A familiar example is afforded by projectiles fired from a gun. When the elongated, instead of the old spherical, projectile first came into use, it would quite often tumble end over end when fired, and was quite as likely to hit the target broadside on as with its point. This was remedied by rifling the gun; that is, by imparting to the projectile a rotary motion about its own axis. The projectile, when rotating in this way, vigorously resists any attempt to change the direction of its axis, so that the point always goes first. Another familiar example is afforded by the game of quoits. We all know that we are much more likely to ring the peg if, when we throw the quoit, we give it a twist. When we give it such a twist, we start it rotating about an axis, and this axis tends always to preserve its original direction, so that the quoit hits the peg at the proper angle. The diagram, showing the quoit in several positions, with the imaginary axis drawn, will make this clear.

THE PRINCIPLE APPLIED TO THE COMPASS

This, then, is the first principle of the gyroscope; that the axis, so long as the gyroscope is turning, tends always to point in the same direction. Let us now apply this principle to a practical case, which will suggest one of the applications. Suppose that we have a heavy gyroscope, so skillfully constructed that it will run a long time, perhaps several days, without stopping. Now let us start this gyroscope some morning toward the rising sun, with its axis fixed pointing east and west. Then as the day goes on and the earth rotates beneath the gyroscope, the axis of the gyroscope will no longer point in the direction it did at sunrise, but will be turned in another direction by the rotating earth, so that at nightfall it might be pointing at the rising full moon. But, as we have seen, the gyroscope resists the change of direction of its axis, so that we should have to apply a force to keep it moving with the earth. But now let us suppose that when we start the gyroscope in the morning, we point it at the north star, instead of at the rising sun. Then, as the earth revolves and the day wears on, the direction of the axis of the gyroscope will not be changed by the rotation of the earth, because the earth's axis itself always points toward the north star. The gyroscope will, therefore, remain in its original position without compulsion. This, then, is the principle of the gyroscopic compass, that if the axis of a gyroscope which is perfectly free to move is pointed at the north star, it will never tend to leave this position, and can be made to do so only by the application of some force. The earth may rotate beneath it, or the ship carrying the gyroscope may maneuver as it will; the axis of the gyroscope will always point true to north.

In the practical use of the gyroscope as a compass for navigation, it is easy to see that there are a number of technical difficulties to be overcome. For instance, the gyroscope must be supported without friction, so that it may be free always to point north, and some means must be provided for always keeping it rotating at a high rate of speed. In addi-



THE GYROSCOPE PRINCIPLE ILLUSTRATED IN A GAME OF QUOITS

The twist given the quoit as it is thrown starts it rotating about an axis, which tends to make it preserve its original direction.

tion, there are numerous disturbing effects which have to be automatically corrected in some way. Such effects are due to the motion of the ship itself as it moves over the surface of the earth. All of these difficulties have been most ingeniously and successfully overcome by E. A. Sperry, the inventor of the Sperry Gyro-Compass. This compass is now in successful use, especially on battleships, where it has particular advantages over the old magnetic compass. The reason for this is that a battleship is made of steel, which itself attracts the magnetic needle. As a result, every magnetic compass has to be particularly adjusted for the individual ship on which it is to be used. But in time of battle, large masses of metal are likely to be displaced by the enemy's gunfire, so that the compass may fail at a time when especially needed. The gyro-compass has none of these disadvantages, and has a number of other important advantages as well.

EFFECTS OF THE GYROSCOPE'S RESISTANCE TO CHANGE OF DIRECTION

In order to understand other applications of the gyroscope, we now have to inquire a little more in detail the precise way in which a gyroscope resists an attempt to change the direction of its axis. The diagram will show how this occurs. This diagram shows simply the revolving wheel with its axle, and for the sake of simplicity does not show the system of rings by which the gyroscope is supported but at the same time is left free to move in any direction. Suppose now, that the gyroscope is rotating as shown by the arrow, and we try to change the direction of its axis by pressing sidewise on the axle, as shown at *P*. Then we will observe that the end of the axle tends to rise, and that after the force *P* has been acting for a short time, a considerable force would be necessary to keep the axle from rising. If the tendency to rise is not resisted, the end of the axle will rise, and the gyroscope will continue to turn round in a vertical plane as long as the force *P* acts. This motion of the end of the axle at right angles to the direction of the applied force is called "precession."

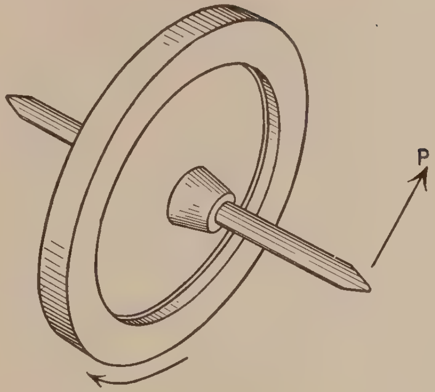
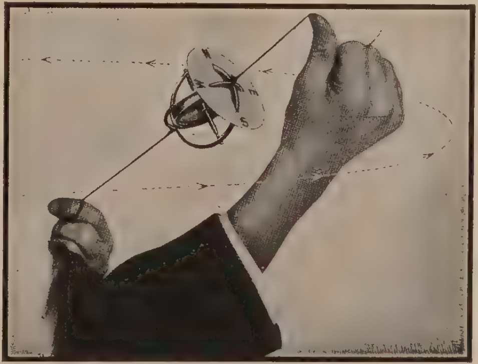


DIAGRAM OF REVOLVING WHEEL

Observe that we have here two remarkable phenomena, in which the gyroscope is different from most mechanical systems with which we are familiar. In the first place, a force here tends to produce motion in a direction at right angles to that in which it is applied, and in the second place, a small force acting for only a short time tends to call forth from the gyroscope a very much greater force. As showing how much greater the force called forth is than the applied force, we may quote an example given by Professor E. V. Huntington of Harvard University. If we suppose that the wheel is a solid disk weighing 3200 pounds, of two feet radius, rotating about the axle, which is four feet long, at a speed of 3000 revolutions per minute, then if a force



THE GYRO-TOP, SHOWING THE PRINCIPLE OF THE GYRO-COMPASS of only 50 pounds is applied horizontally at *P*, in one half of a second it will have called forth a resisting force in a vertical direction of 16,000 pounds. This means that in one half second we could call into play with this particular gyroscope a force 800 times as large as the force we apply.

A GYRO-COMPASS

THE MONORAIL CAR

It is to this fact, that the resisting force is so very much greater than the applied force, that the gyroscope owes many of its applications. One of the simplest applications is to the Brennan monorail car. This is a car designed to run on only one rail, and is kept from falling over by a gyroscope. If the position of the load changes, as by a man walking from one side of the car to the other, or if the wind rises and tends to blow the car over, the gyroscope automatically shifts the position of the car, so as to make it balance under the new conditions. This is done by an automatic device so arranged that when the car begins to tip slightly a small horizontal force is applied to the axle of the gyroscope, which immediately responds with a very much greater vertical force in such a direction as to force the car back into its position of balance. This holds true whether the car is moving or stationary; there is nothing of the principle of the bicycle here. The advantages of such a car are great, in that the large expense of the carefully constructed roadbeds which are necessary for the attainment of high speed with our present trains would be done away with. It would be particularly easy to construct a railway of this type through virgin country. Probably all of us have seen pictures of trains running across yawning chasms on a single wire cable, a feat perfectly possible to cars of this type. As is the case with all inventions, there were a number of technical difficulties in the way of the application of this simple idea. Some of them have been surmounted in the case of the monorail car by the use of two gyroscopes, rotating in opposite directions. But this car has now successfully passed through the experimental stage, and we may soon expect its practical use, especially in those cases where the construction of a two-rail track would entail high expense.

A STABILIZER OF SHIPS

Besides the gyro-compass, we owe to Mr. Sperry another important application of the gyroscope. This is in stabilizing ships. The essential idea is similar in many respects to that of the monorail car. As the ship rolls, a device automatically applies to the gyroscope a small force which calls forth a much greater force in such a direction as to counterbalance the tendency of the ship to roll. The advantages of a nonrolling ship are obvious to anyone who has traveled by sea. In addition to doing away with physical discomfort, a nonrolling ship would have many economic advantages, because it takes less power to drive a ship which does not roll. The advantages for a battleship going into action in a heavy sea are obvious. This problem has been attacked before and partially solved by some German engineers, who use for the purpose large tanks of water, in which the rolling of the ship sets up waves that tend to counteract the rolling of the ship. The gyroscope had also been tried before, but in another form. None of the early devices are nearly as efficient or as economical, however, as the Sperry stabilizer. This has been tried on a large scale on the U. S. S. *Worden*, and has been strikingly successful.

Another possible use for the stabilizer has been suggested by Sperry. If a gyroscope can be used to prevent a ship from rolling in a heavy sea, we may work the machinery backward and use the gyroscope to roll a boat, if we wish, in a quiet sea. Such an artificial rolling would be of very great value in such boats as ice breakers.

STEERING TORPEDOES AND STABILIZING AËROPLANES BY THE GYROSCOPE

Finally we may mention two other important uses of the gyroscope. The first of these is perhaps the first use to which it was put; namely, in steering torpedoes. This was first done by Obry, an Austrian naval officer, and is now used in practically every type of torpedo. The torpedo is kept true to its course under water by an undeviating gyroscope so connected with the rudder that it keeps the torpedo always in its own direction.

The other application is in stabilizing aëroplanes. At first, when this use of the gyroscope was originally suggested, inventors seemed to have the idea of keeping the aëroplane on its course by the sheer brute force of a gyroscope, which should grasp the aëroplane in a giant hand and compel it to preserve an undeviating direction. But it was soon proved mathematically that this would require a heavier gyroscope than any aëroplane could carry. Recent attempts, however, seem to be more promising. One of these is the Sperry stabilizer. This consists of a number of gyroscopes so connected with the levers of the various planes that when the aëroplane deviates from its course the gyroscopes automatically work the levers and keep the aëroplane on its course, just as the aviator would work the levers if he could attend to all things quickly and surely. This has been applied with prospects of success.

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A GAS VICTIM REVIVED BY THE PULMOTOR

A MECHANICAL LIFE-SAVER

THE pulmotor is a device for saving the lives of persons who have been apparently drowned, or who are overcome by fumes, gases, or by electric shock. The apparatus forces air charged with oxygen into the lungs and withdraws the deoxygenated air, regularly, as many times a minute as a well person ordinarily breathes. The pulmotor apparatus weighs about fifty pounds, so that it can be carried easily in an ambulance or an automobile, in case of a sudden accident. It consists of a cylinder containing pure oxygen; the gas is conveyed through a tube to an injector, which is so arranged that it can draw in a large volume of air by suction through one tube, and also propel air and oxygen forward with equal force through another tube. This suction and delivery injector is really a motor, which alternately fills the lungs by pressure and empties them by suction. Two flexible tubes connect the injector with the face mask. One tube supplies pure air and oxygen, and the other exhausts the air breathed from the lungs.

Life-saving stations, fire departments, hospitals, mines, and factories have found this apparatus far more effective than any other method in restoring persons whose breathing has been seriously interrupted or stopped entirely.

BRIDGING TIME AND SPACE

An important invention which makes new use of a scientific fact is likely to be followed by a group of lesser inventions which use its principle for the convenience of mankind. The telegraph, the telephone, and the phonograph were three epoch-making inventions. The telegraph made use of an electric current to carry messages over a wire; the telephone made use of the same type of current to carry the spoken word over a wire, introducing receivers and transmitters at each end of the wire; the phonograph added cylinders on which the spoken word could be recorded permanently. These three inventions opened up that field of discovery. Similar inventions were soon derived from them which served specific purposes in the business and social world.

THE DICTAPHONE

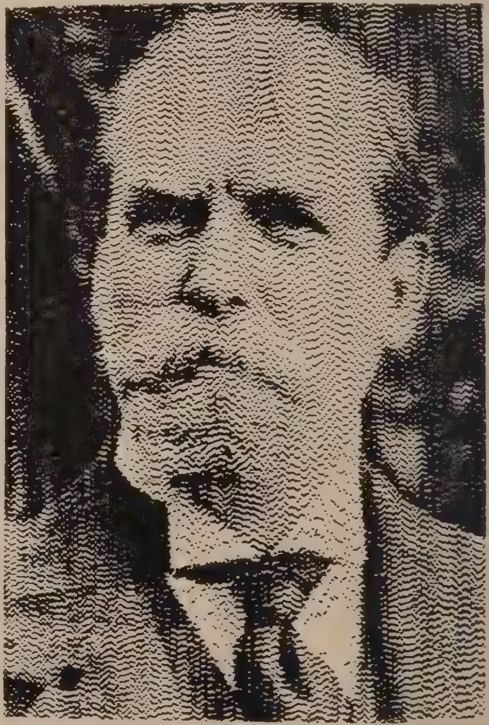
The dictaphone is a form of phonograph that records business letters, professional reports, and similar matter, to be transcribed later on the typewriter. The apparatus consists of a stand or frame bearing the special recording phonograph, which occupies about as much space as a typewriter. The wax cylinders of the machine are driven by electricity. As the person dictating talks into the mouthpiece of a tube his remarks are recorded, and they can be reproduced and typewritten at any later time.

The expert stenographers who report the speeches of the members of Congress in the Capitol at Washington make use of several dictaphones. These stenographers work in shifts, and each man takes notes for about an hour at a time. He then goes to a quiet room and reads his notes slowly and distinctly to the dictaphone. As fast as the wax cylinders are filled, typewriter operators remove them and place them on reproducing phonographs. The operators then typewrite the notes, and the typewritten copies are forwarded at once to the Government Printing Office.

THE DICTOGRAPH

The dictograph is a magnifier and transmitter of sound. Not only the tones used in conversation but also whispers, the rustling of clothing, the fall of a pin, the slightest noises, — all are conveyed by this curious apparatus.

The dictograph is the development of an instrument which was designed to help the deaf to hear. The apparatus consists of a sound collector, or transmitting disk, of hard, black rubber, a receiving disk, a battery or two, and transmission wire. It is an enormously sensitive telephone transmitter, which catches every sound within a considerable radius and transmits it to any desired distance. The dictograph has been of great service to detectives and police in enforcing the laws. It has brought about the conviction of many suspected criminals, for the instrument has transmitted their conversations and has enabled the officers of the law to learn the plans of lawbreakers, or to listen to their admissions of guilt. When used for such purposes the transmitter is placed any-



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ONE OF THE FIRST PHOTOGRAPHS SENT BY RADIO

In 1924 this photograph of Mr. Hughes, then Secretary of State, was sent across the ocean in twenty minutes.

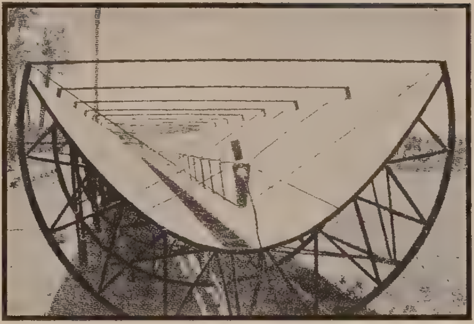
where in the room where the person whose evidence is desired will be most likely to talk. It can be hidden under papers upon a table, or hung on the wall behind a picture or calendar. A fine silk-covered wire runs from the transmitter through a tiny hole in the wall or floor to another room, where the person who holds the receiver can hear every word spoken in the room where the transmitter has been placed, and can write it down in shorthand, if he so desires.

FINGER PRINTS FOR IDENTIFICATION

The scientist discovered that the finger prints of any person were so individual as to form a means of identification, since they differed from those of all other persons. The police and detective agencies of the country turned this information immediately to the purposes of justice, by taking the finger prints of all persons suspected of crime or known to have committed crimes in the past. Within a few years this method of identification became a commonplace of the courts.

PHOTOGRAPHS BY WIRE AND RADIO

Meanwhile the science of radio had come to be understood. The wires of the telephone and the telegraph were not essential for long-distance communication. Messages could be sent around the world in a few seconds by a process of wireless telegraphy and telephony. The inventors did not stop there. For years there had been research going on in the laboratories to perfect methods of sending photographs by the dot-and-dash method over the telegraph wires. The "telepix" was one of the first mechanical devices which accomplished this feat in 1924–1925. In the same year there came over the telephone wires pictures so perfect that one could hardly believe that the actual plate on which the photograph was taken had served only as a basis for transmission by wire of its elements of light and shade. (See page 61 of this volume.) While the world marveled over these wonders, the first photographs were being sent across the ocean by radio. By the same method finger prints were being transmitted from New York to Chicago and San Francisco and located in the files. The criminal who had hoped to escape his past by traveling a few hundred miles was confronted with his record within a few minutes, or at most a few hours. The bridging of time and space which began in the nineteenth century has been marvelously fulfilled in the twentieth.


A SUN-HEAT ABSORBER

ENERGY DIRECT FROM THE SUN

THE sun is the great source of energy for mankind. But we obtain much of its gift to us indirectly, through the burning of wood and coal, and through the other means for breaking down the compounds which it has built up. Men are always seeking means of obtaining that energy direct from the sun without these intermediate stages.

Not far from Cairo, Egypt, where the sun shines every day the year round, there is a curious engine which obtains its power, not from the combustion of coal or oil, but from sunlight. The boiler of this engine, part of which is shown in the picture on this page, is very different in almost every way from an ordinary boiler, for it is made mostly of zinc, or steel and glass. The sun-power plant near Cairo has five long rows, or troughs, of silvered-glass mirrors, which catch the rays of the sun and concentrate them upon the actual boiler, a rectangular upright metal box in the center of the trough. These long rows of mirrors point north and south and turn on their axes to face the sun, at whatever point it may be in the heavens. The steam collected by the heating of the water in the trough is collected at one

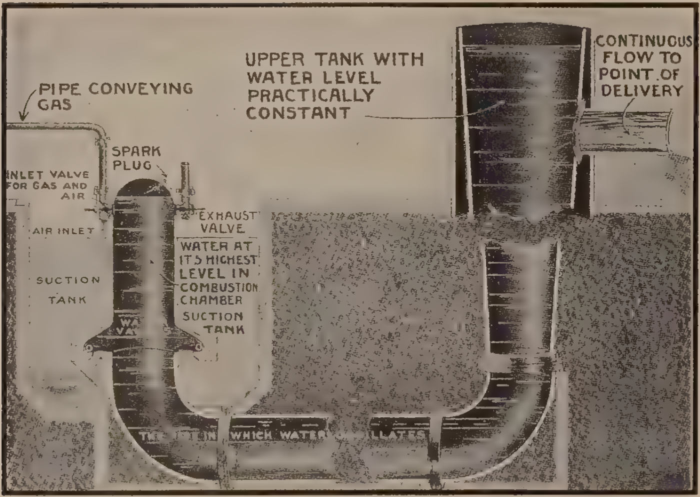

PIPE CONVEYING GAS
UPPER TANK WITH WATER LEVEL PRACTICALLY CONSTANT
CONTINUOUS FLOW TO POINT OF DELIVERY
SPARK PLUG
INLET VALVE FOR GAS AND AIR
AIR INLET
EXHAUST VALVE
WATER AT ITS HIGHEST LEVEL IN COMBUSTION CHAMBER
SUCTION TANK
SUCTION TANK
WHICH WATER
LLATES

DIAGRAM OF GAS-EXPLOSION PUMP

end in a pipe four inches in diameter; water flows in at the other end. The steam pipes from the various units of the plant discharge into an eight-inch main pipe which carries the steam to the engine, enabling it to pump water at the rate of twelve thousand gallons a minute. It is still uncertain whether the solar engine is practical and economical, when its cost and complex parts are taken into account. But it is of great interest in the way it gets its power.

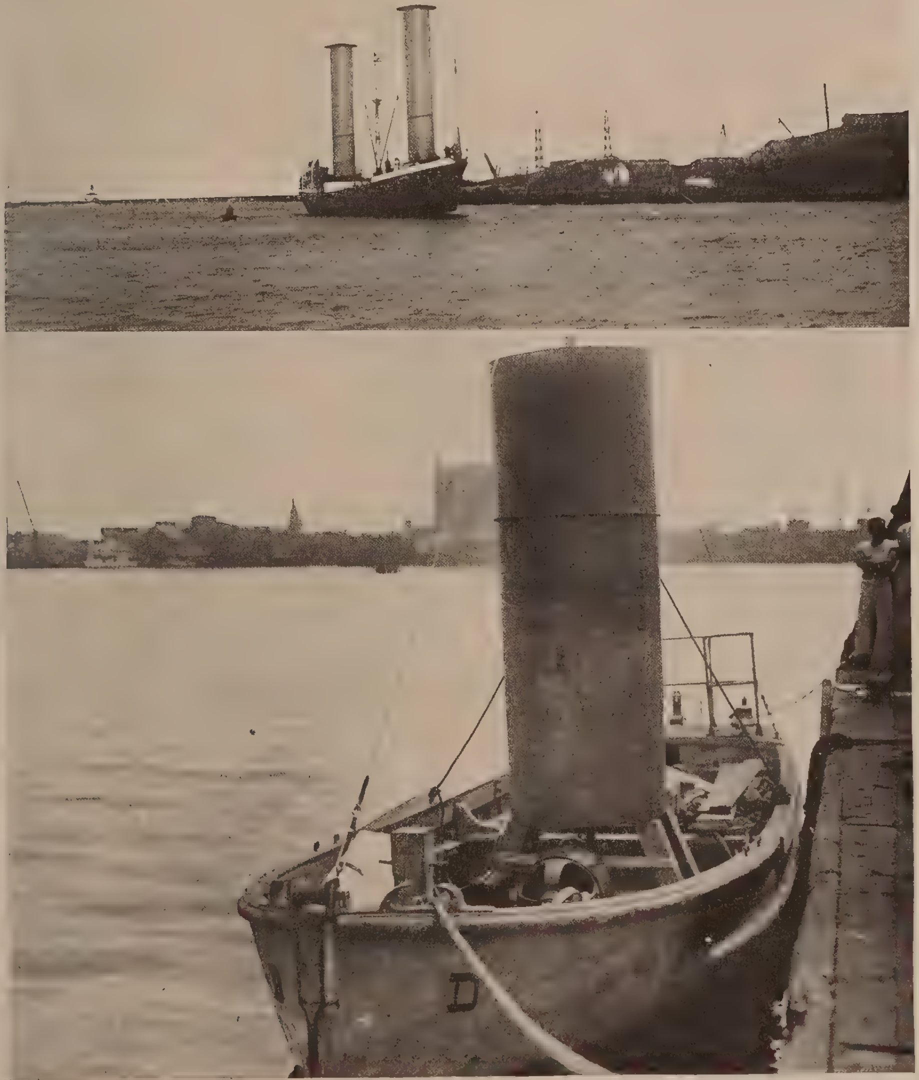
In similar ways scientists are trying to harness the energy known to exist in the atomic structure of matter. (See Volume Eleven, page 321.)

WATER CANNON

An English engineer has invented a remarkable pump which is unlike any other in existence. The pump is really a gas engine in which water takes the part of piston, connecting rod, and flywheel. Our picture from the London *Sphere* shows how it operates. At the left is the pipe that conveys gas to the combustion chamber. The water enters this chamber through valves from the suction tank. As the water rises it compresses the air and gas, the valves close, and the spark plug at the top of the chamber ignites the mixture of gas and air. The explosion forces the air down the cylinder through the pipe at the bottom and up to the point of delivery on the extreme right. There the water gushes out into the reservoir. About twelve explosions take place every minute. The spark plug is ignited in an ingenious way. At the top of the combustion chamber there is a small chamber in which a little piston makes and breaks the current by rising, when the gas is being compressed by the upward swing of the water, and falling when the water recedes. The spark, therefore, ignites the gas practically at the highest point of combustion. This novel pump works on about the same plan as a cannon loaded with water, instead of with a projectile. Five gas-explosion pumps lift water from the River Lea into one of the three-billion-gallon reservoirs that supply London with water. The Egyptian government has ordered ten pumps to pump water from the delta of the Nile near Alexandria. These ten pumps will raise one billion gallons of water a distance of twenty feet daily. The Nile delta will soon have the largest pumping station in the world.

THE INVENTOR AND THE SCIENTIST

Invention follows hard upon the heels of knowledge — indeed, sometimes leads the way. Practical use of electricity, for example, far outstrips scientific knowledge of that marvelous force, although the scientists are beginning to catch up with the inventors in this field. Of course electricity was known before the inventors found its manifold uses; but it was that use which the inventors made that led to the real knowledge of electricity. Faraday and Franklin precede Morse and Gray and Edison; but these, in turn, precede Clerk Maxwell. And this is the history of the relation between science and invention in all lines. Laboratory experiments by a few



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THE ROTOR SHIP — A SAILING VESSEL WITH NO SAILS

As a spinning baseball is deflected by the whirl of the air around any spinning body from a straight line into a curve, the revolving towers of the rotor ship serve as sails, producing a pressure at right angles to the direction in which the wind blows against them. Above is the original Flettner rotor ship with two revolving towers (50 feet high, 10 feet in diameter); below is the interior of an American rotor ship with one tower. The towers are revolved by electric motors. The advantage of these curious, experimental ships is that only a very small crew is required to operate them.

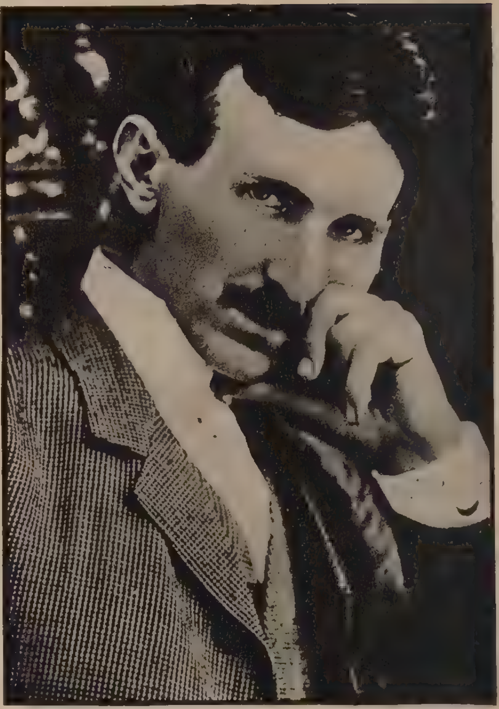
scientists with more imagination than their fellows, or better luck, throw out a hint as to some new force or new applications of well-known laws. The inventor is sure to seize on the hint. A practical development of the newly discovered force is worked out. This development leads the way to new knowledge and sets the whole world of science to thinking.

While it might not be admitted by scientists that Marconi and Tesla have increased knowledge or altered the scientific outlook, there can be little doubt that the marvelous discoveries of these men have pointed out the directions in which new knowledge of this wonderful universe lies open to man.

TESLA'S TURBINE

No one thinks of steam or gas as a sticky substance. If you pour water on a smooth surface, such as steel, most of it will roll off, but not all. Some will *stick*. All fluids and gases have this quality. It is what makes the ship designer reduce the surface of his vessel to lower its "skin friction." There is nothing very new about this. The world has known of it for centuries, to some extent. It has always been regarded as a great nuisance — a thing to be overcome, like weeds in a garden. It has interfered with the engine builder, the machine maker, the constructor of all kinds of delicate apparatus. He could not get along without it, nevertheless it has always been in his way. Now comes Nikola Tesla with his wonderful turbine and makes use of this force — transforms the old hindrance into a new help. It is the old story, "The stone which the builders rejected has become the head of the corner."

You have watched a stick or a log dragged along by the current, and you know that if the current is strong and the stick heavy the force of its movement is sufficient to endanger bridges and huge embankments. Now, the drag or stickiness of a moving gas is even greater than that of a moving liquid. So that if you have a current of steam moving with great force and some object floating in it, that object will be carried along with great force. The steam will not let go of it easily. The object moves much as a spear would while you grasped it with your hand and swung your arm forward. As long as you held the spear tightly, it would move with all of the force and speed of your arm. So steam grips an object that is floating in its current, and carries it with it. The greater the surface of the object, the more the steam sticks. Tesla's turbine balances a wheel in a current of steam or gas in such a manner that it is caused to rotate, not by the *push* but by the *pull* of the steam. Of course, he must make the surface of his rotary as large as possible. We may describe Tesla's turbine as a series of disks fastened to an axle, and surrounded by a gas-tight casing. The steam is admitted on the outside edge, at a tangent to the circle of the disks. The steam follows the disks and, in its circular motion, drags them around with it, passing out by a hole at the center of the disks. The inventor claims that he can produce millions of horse power in a single plant by this process.



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NIKOLA TESLA

TESLA'S OSCILLATOR

In the spring of the year 1899 Tesla began serious experimentation in high-tension electrical currents, as they are called. The central feature of his work, which was picturesquely carried on among the mountains near Colorado Springs, was his wonderful oscillator — wonderful in its results and in the faith which led the inventor to make the heavy investment necessary to test the idea on a large scale. For there are many things that work very well in small laboratory experiments, that prove to be entirely impracticable for actual use under working conditions. Tesla's oscillator, in itself, is a very simple thing. It combines the alternating current, with which we are already familiar, with the tuning device and helial of a wireless outfit.

In this way a current from a high-power alternating dynamo is sent directly into the earth and air. One would think that this would surely be to throw the expensive power away. The earth is like a huge sponge, soaking up electricity more readily than it soaks up water. Ah, yes. But Dr. Tesla reminds us that it also transmits electricity with great ease. All that is necessary is to regulate ("tune") the current sent into the earth in such a way that it will be taken up by a receiver tuned to the same length of vibration; and your current, instead of being lost, is transmitted, and with amazingly little loss. Tesla has succeeded in producing wonderful effects — flames, seventy feet long, of electricity rising from the very earth! But would not such currents, passing through earth and air, destroy life — becoming unruly, like lightning, which, in this experiment, they so closely resemble? The inventor answers by allowing one of his most powerful currents to be intercepted by his own head! What the final results of these experiments will be, we cannot tell. They seem to open the doors to an entirely new wonder world.

WHO IS NIKOLA TESLA?

He is an Austro-Hungarian, born in Smiljan in 1857. He was graduated from the Polytechnic Institute of Gratz and from the University of Prague. In 1881 he established himself in business as an electrical engineer. In 1884 he came to the United States and entered the employment of the Edison Company. He has given his attention to the most advanced problems of electric transmission, and is well known as a scientific authority as well as the inventor of many devices. Perhaps his most important practical invention has been the use of a rotating magnetic field on alternating-current generators. By this means alternating currents may be sent from large power plants over great distances.

THE INVENTOR'S USE OF HIGH TEMPERATURES

Here again the inventor turns scientist, or the scientist turns inventor, if you prefer to put it that way. The action of materials under the influence of very high temperatures differs not only in degree but also in nature from their action under ordinary temperatures. Some of these differences are used by inventors and have already revolutionized the practical way of doing many simple things. The whole subject is another of those which lie on the borderland of the unknown, and which open up possibilities of which we dare not prophesy — not for fear that we shall be extravagant, but for fear that we shall limit the truth.

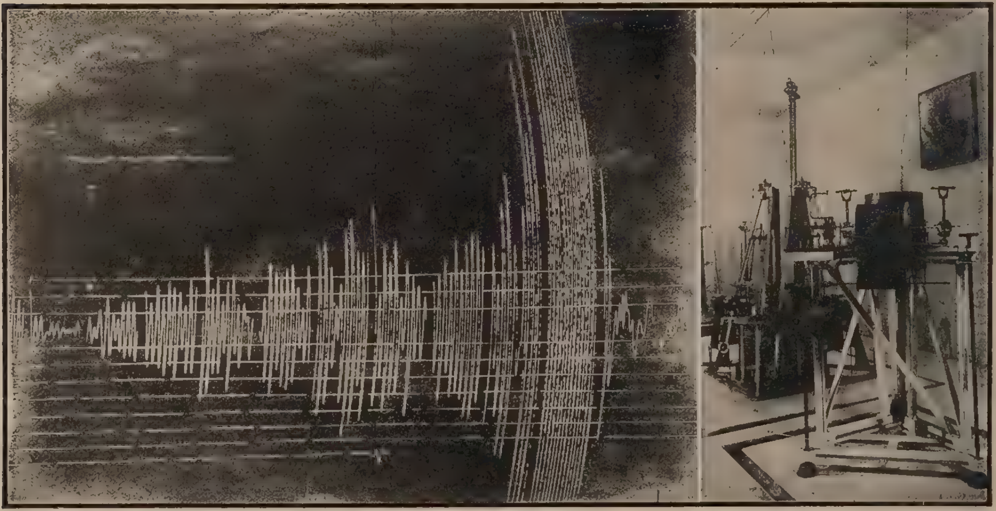
THERMIT WELDING

Dr. Hans Goldschmidt has the honor of bringing to notice this useful device. It has been described elsewhere, under the head of Applied Science, and need not be further explained here. But it is of interest to us to note the part it has played in convincing the commercial world of the enormous benefits to be derived from modern scientific knowledge. The violence with which certain chemical reactions are produced and the great heat which they engender have been familiar facts in all laboratories for a long time. The thermit makes use of the high attraction of aluminum for oxygen. The oxygen in the thermit is contained in iron oxide. This iron oxide is mixed, in a powdered state, with powdered aluminum, a little heat is applied to start the reaction, which, as soon as it is under way, produces the heat for its own progress. The oxide leaves the iron, which is melted to a fluid state, and separates from the aluminum, which becomes alumina. The intense heat so thoroughly fuses the iron that it can be used to weld the heaviest beams in use. A further use of the thermit is likely to arise in securing pure metals, as the reaction eliminates the most common impurities.

CUTTING STEEL BY HEAT

A French inventor, Le Chetalier by name, taught the world the use of the high temperature produced by a flame of burning acetylene gas and oxygen. He invented a torch for burning this mixture of gases and directing the heat to a sharply focused point. Now it seems to be one of the peculiarities of very high temperature that it does not spread in the same manner as low temperature. By directing this thin, intensely hot flame against a plate of steel, the heat cuts its way through the metal in a sharp line, and the metal on each side of the cut remains uninjured. If you watch anyone using this torch, you will see, in a moment after the heat has been applied, a little shower of sparks appear from the opposite side of the plate. The flame has cut its way through. Now, if the workman passes the flame slowly along the line he wishes to cut, the plate will be severed as cleanly and perfectly in a few minutes as it could have been done with a saw in as many hours. More than this, the temper of the most finely tempered steel will remain uninjured. This is the most extraordinary fact of all. For if you were to put such a piece of tempered steel into an ordinary fire, you would soon destroy its temper. Indeed, care must be taken, even in sawing it, that the heat of friction is not too great, or the temperature will be "drawn," as it is called. Here again we are face to face with new wonders of natural law.

The acetylene torch is also used for welding great shafts, and this can be done, often, without removing the broken part from the machine. In other words, what a few years ago would have been difficult and costly to repair can now be accomplished at comparatively slight expense and with great ease.



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A SEISMOGRAPH, WITH ITS RECORD OF AN EARTHQUAKE SHOCK

By scratching across the sooted surface of this smoke sheet on revolving drums, the platinum pens of the seismograph have left their record of earthquake disturbance. These instruments are so delicately adjusted that they record not only earthquake shocks, but the slightest movement or tremor of the earth's crust, thus making it possible to study at a chain of stations which encircle the earth the slightest variation from normal. It is predicted that by the new science which is being developed from these observations it will be possible to give advance warning of earthquakes.

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CENTRAL HALL OF THE PATENT OFFICE

HOW INVENTIONS ARE GIVEN TO THE WORLD

LET us consider how inventions are applied to the practical uses of the world. Every new invention or discovery was born in the brain of some man or woman, sometimes by accident, but more usually after prolonged study and experiment. You remember that Sir Isaac Newton, when asked how he discovered the law of gravitation, replied, "By constantly thinking about it."

Naturally the first thing that occurs to a man who has invented some new and useful idea is to safeguard it by patenting it; otherwise unscrupulous persons will steal it from him.

Patent laws have been framed by practically every civilized nation to give to any person applying the exclusive right to the manufacture, use, and sale of his own invention for a certain period of years. After that it becomes public property, and may be freely manufactured by anybody. In the United States this period is seventeen years. A patent is something like a contract between the government and the inventor or patentee. The meaning of the word "patent" is "open," and openness is the keynote on which the contract is based. In other words, the inventor must fully disclose the nature of his invention or discovery and allow the public free use of it after his term has expired. If he should conceal a part of the truth, he has failed in his contract with the government, and his patent is null and void.

HOW TO SECURE A PATENT

In order to secure a valid patent the applicant must declare upon oath that he believes himself

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THE "JOHN BULL" LOCOMOTIVE, 1831

to be the "true, original, and first inventor or discoverer of the art, machine, manufacture, composition, or improvement" for which he solicits a patent. If the invention, however, has been in public use or on sale for a period of two years, it becomes public property, and the inventor cannot secure a patent. A man of any nationality can secure a patent under the laws of the United States. If, as sometimes happens, two persons have invented the same thing at or about the same time, "interference proceedings" may be instituted to determine which applicant is the original or first inventor. Careful investigation is made of the claims of the rival inventors and a fair decision arrived at.

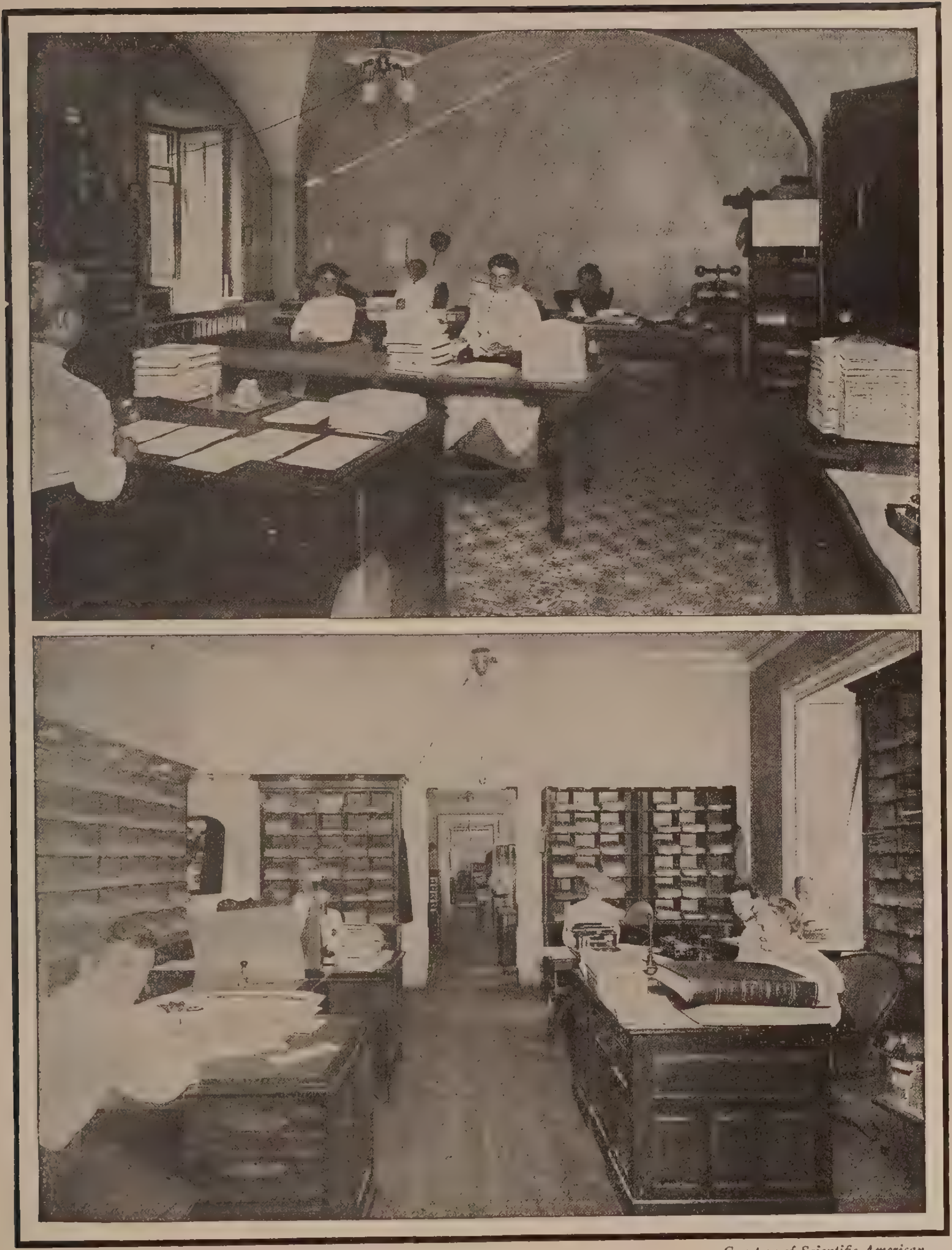
To secure a patent the thing invented must be *new* and *useful*. The inventor must submit to the patent office a written description and drawings of his invention, together with his special claims for it. A search is then made through the files of the patent office among patents already issued. If specific proof is found in this way that the invention is not original, the patent is denied.

If a man has infringed upon the patent rights of another, that is, manufactured or sold a patented article, the inventor can, by bringing suit, compel him to desist and make restitution.

Such articles, however, must always be marked "patented," together with the date when the patent was issued or the serial number of the patent; otherwise damages cannot be recovered.

BRIEF HISTORY OF PATENT LAWS

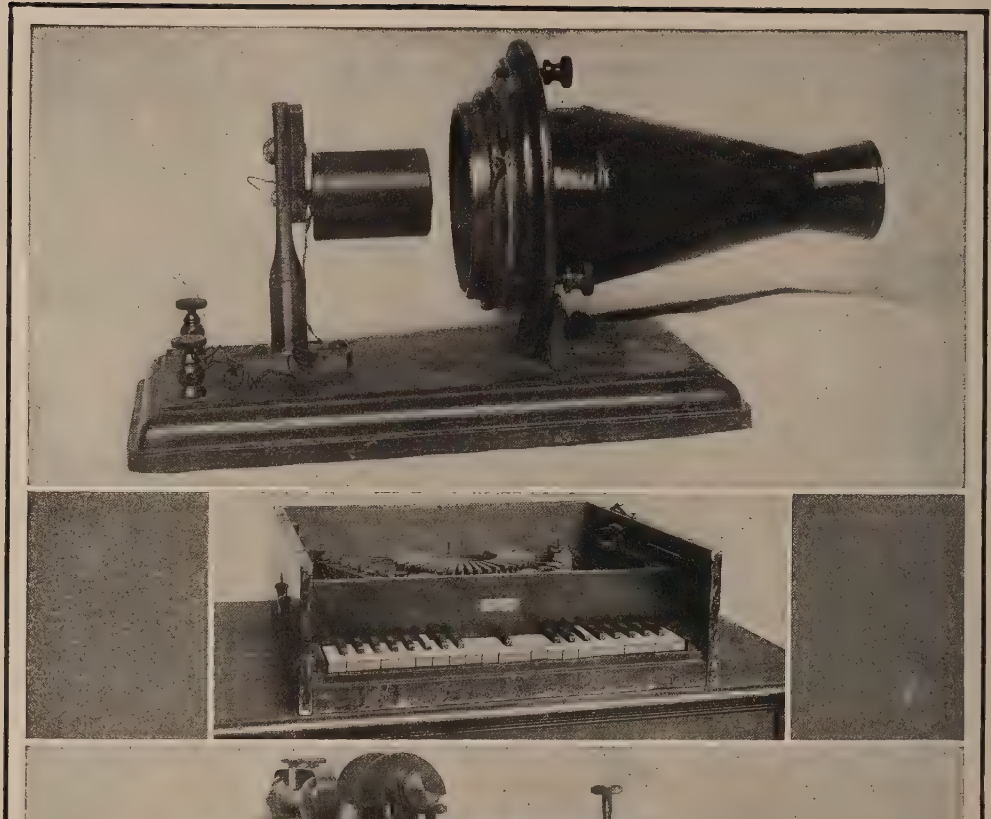
The vast industrial development of our country would never have gone forward as it has were it not for the wise and generous protective patent laws of the United States. Yet there was a time when the system of issuing patents was regarded with distrust and prejudice by the public. This was partly because in England during the reigns of Elizabeth and



Courtesy of Scientific American

WHERE PATENTS ARE TAKEN OUT

Top: The Paste Room, where copies of patents are assembled. Bottom: Issue and Gazette Division, where the completed patents are prepared for issuance.



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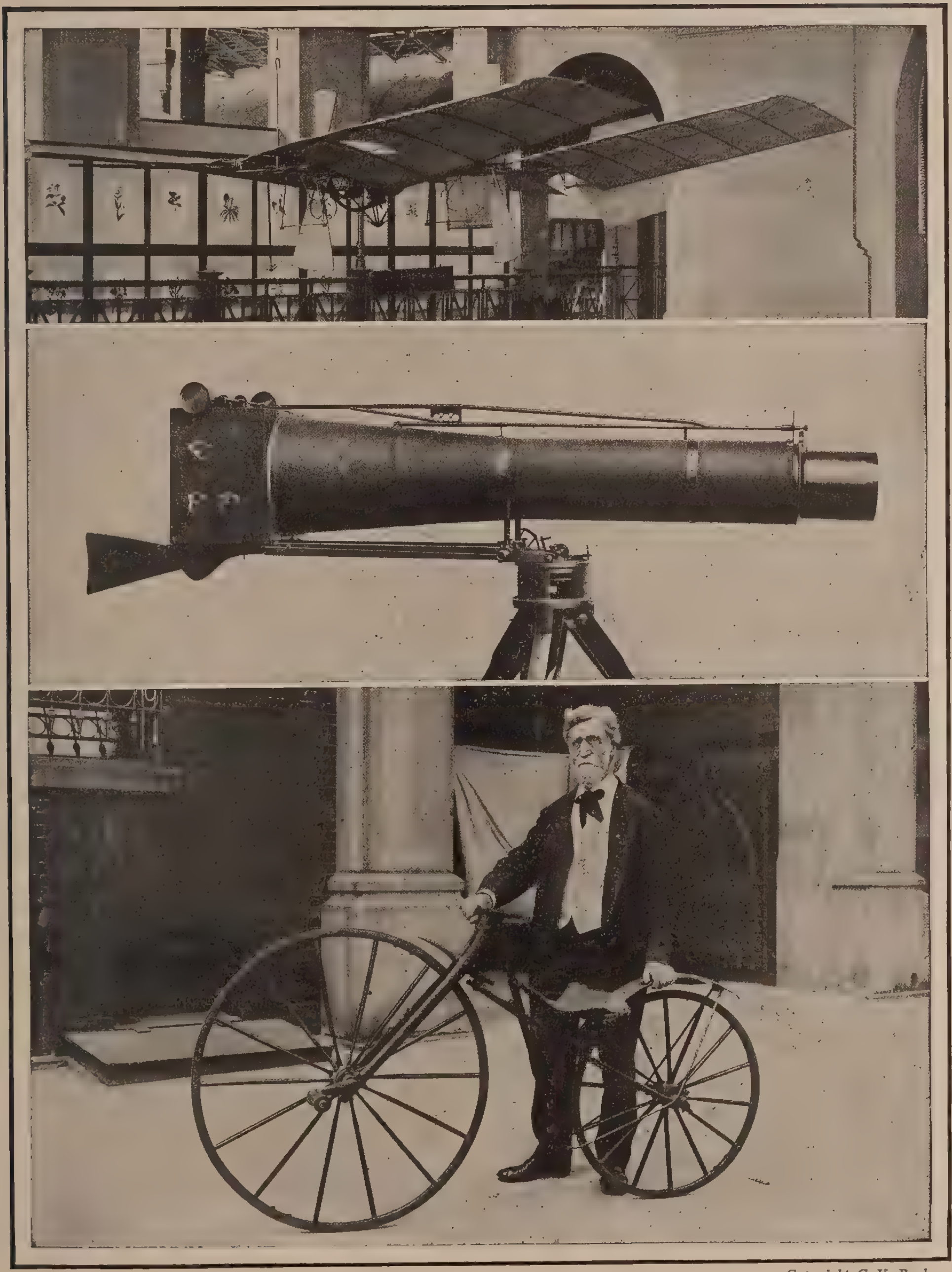
FIRST MODELS OF FAMOUS INVENTIONS

Top: Alexander Graham Bell's telephone, the model submitted in 1876. Center: The Francis typewriter, invented by Samuel Ward Francis, 1857. Bottom: The Morse telegraph instrument used on the Washington-Baltimore line, May 24, 1844.



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FIRST MODELS OF FAMOUS INVENTIONS

Top: Model (one quarter size) of the aërodrome invented by Samuel Pierpont Langley of the Smithsonian Institution. This model made a successful flight in 1903. Center: Langley's gun camera, which he used for the photographic study of the flight of soaring birds. Bottom: An early American bicycle made in Detroit, Mich., in 1879.

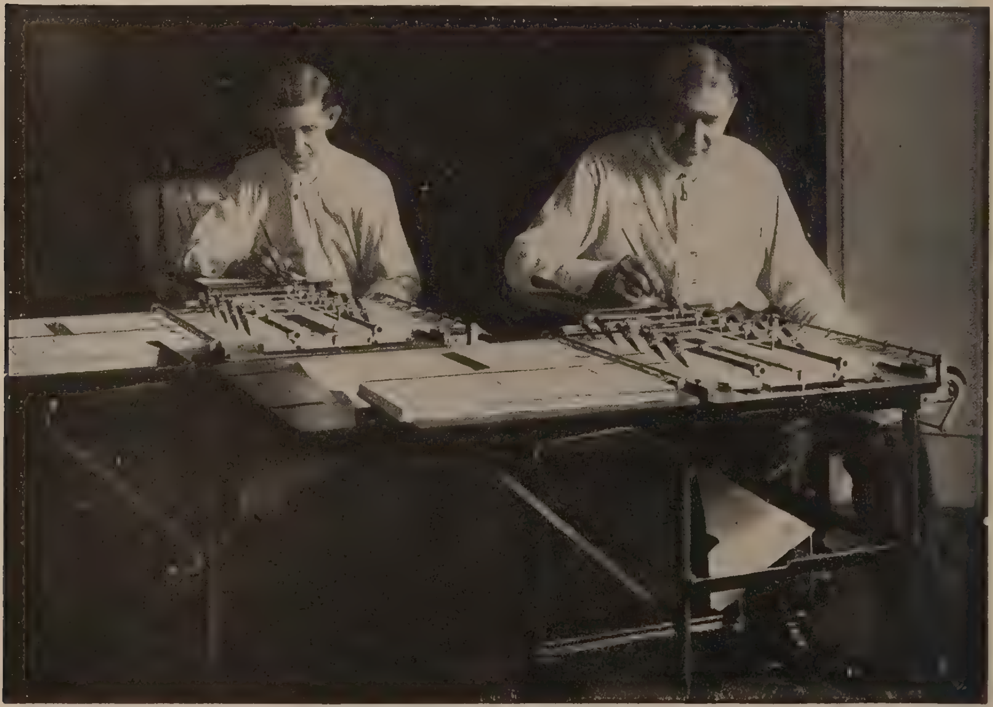
James the practice of selling letters patent or monopolies to certain favored individuals or companies was attended by many abuses.

In early colonial days patents were issued by the colonial governments and later by the several states. The first patent laws of the United States were enacted in 1790, and the first person to receive a patent under them was Samuel Hopkins of Vermont, for a process of making pot and pearl ashes.

But at that time patents were still regarded with suspicion and dislike, and the inventor generally had the worst of it if a question of right under a patent came up for trial. In those early times, too, securing a patent was very expensive, and the inventor, through poverty, was often obliged to keep his invention secret. As time passed a more intelligent public spirit prevailed and patent laws became more just.

By protecting the inventor, the United States patent laws have stimulated inventions and improvements without number in every branch of manufacture, caused the production of newer and better articles, and cheapened the cost of making them. Agricultural implements, sewing machines, bicycles, typewriters, electrical apparatus of all kinds, phonographs and dictaphones, photographic materials, iron and steel products, and rubber goods all owe their wonderful development to patented improvements. And almost everything that the printer touches in his work owes its origin to some patented device or apparatus. The amount of capital invested in the manufacture of all these products is incredible.

We gain some idea of the activity of American inventors when we learn that up to July 1, 1906, the number of patents issued by the United States government was over 850,000. The Patent Office in Washington, where models of the later inventions are kept, is one of the most interesting places in the country.



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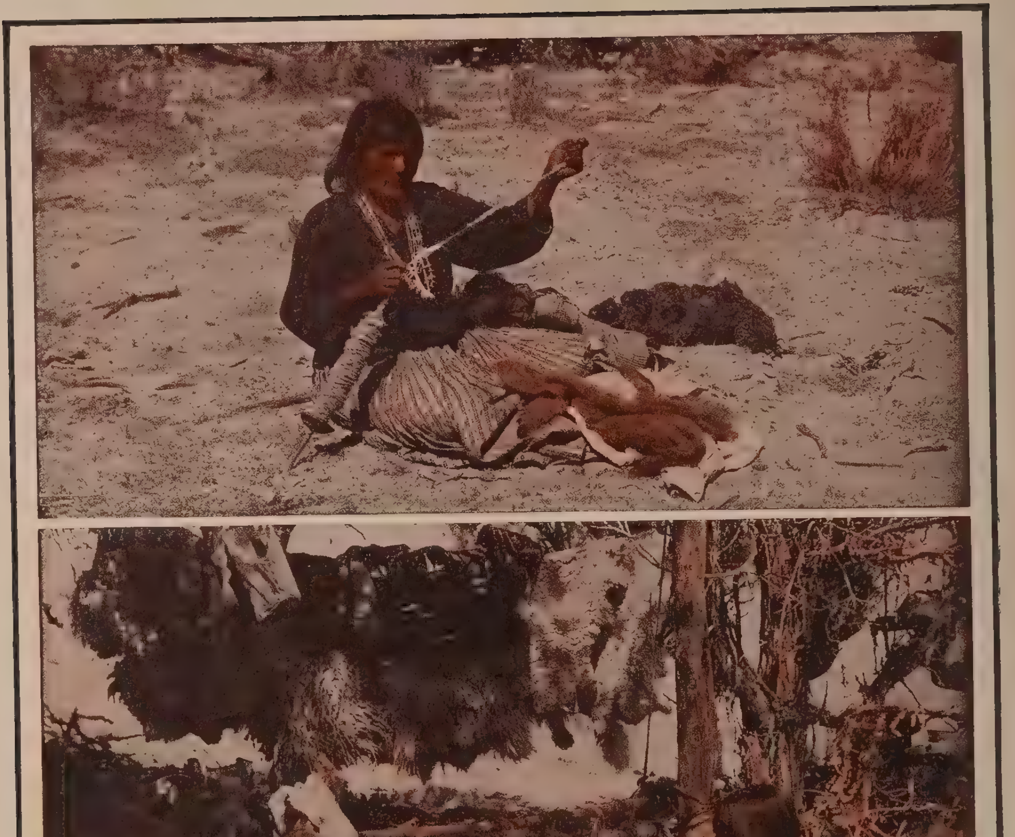
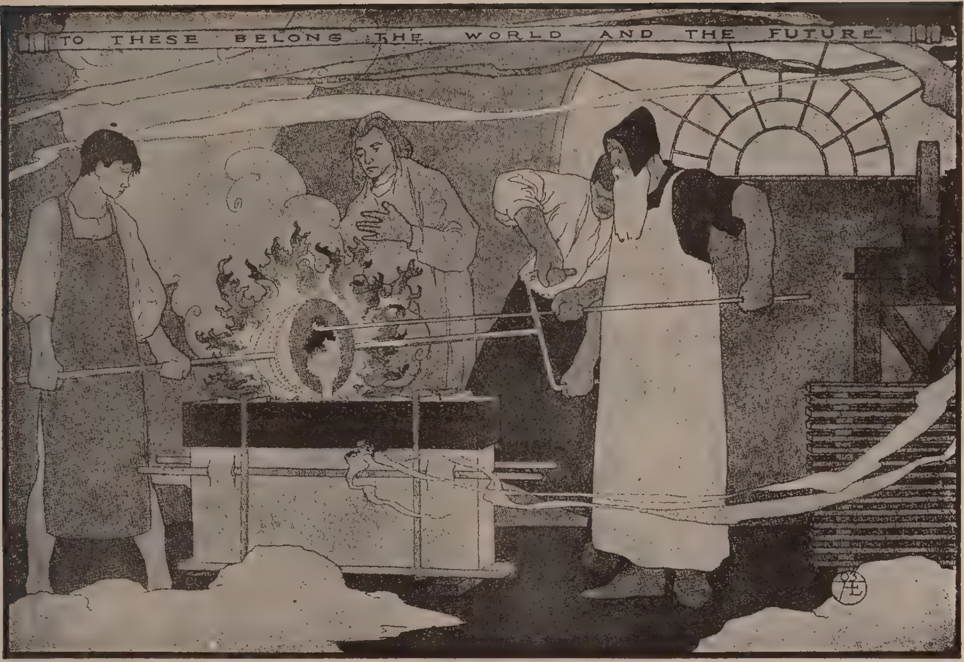
A MACHINE THAT SIGNS TEN CHECKS AT ONCE



SPINNING AND WEAVING, TWO OF THE EARLIEST INDUSTRIES


"TO THESE BELONG THE WORLD AND THE FUTURE"

INDUSTRIES AND OCCUPATIONS

> All these trust to their hands: and every one is wise in his work. Without these cannot a city be inhabited. They will maintain the state of the world, and their desire is in the work of their craft.
>
> *Ecclesiasticus.*

THE germ and subsequent progress of the world's industries had their birth in and were fostered by man's combat against Nature. Had he been born a satisfied being, with no wants which cried out for gratification, he would have entirely lacked the incentive for seeking in the universe about him the answer to his needs. But life was no such uninteresting existence. On the contrary, it was a stupendous conundrum — man being the questioner and the great world the silent response to his queries.

"How shall I keep warm?" asked Man.

"How shall I satisfy my hunger? "

"How shall I protect myself from the elements?"

Mother Nature heard the cry of her child, but she offered no reply. Instead, she dumbly spread out before him her wealth and left it to him to appropriate what he would. Wrapped up in that speechless universe lay the solution of every enigma puzzling him. The key to the riddle he must find himself. Through his ingenuity lay the only path out of his difficulties. He gazed out upon his surroundings with wondering eye. What should he do with the minerals, the plants, and the animals that confronted him at every turn? Since no other means for subsistence was provided it must be possible to convert them into the things he needed.

And so from crude beginnings he struggled with his glorious problem, constantly discovering new uses for the materials that lay at his hand. Gradually he discarded the skins that covered his body for spun cloth, the tent for the roofed-in shelter, the moccasin for the shoe. As the world was peopled, more minds united in solving these puzzles. How could articles be made more quickly, easily, and strongly? No single person could perfect each individual trade, and therefore it followed that while one man bent his efforts to the making of cloth, another turned his attention to making paper. So through centuries of groping experimental work the upward climb to our present-day civilization was made.

Then the population of the world increased, and there arose a mighty clamor for great numbers of the commodities that had previously been turned out in small quantities. Machinery displaced hand labor, and since processes became very complex it was no longer possible for one person to begin an article and carry it on to its completion. Instead, each man became a specialist, performing his minute share in the mighty "team work" of the modern industrial world. By constant practice he became an expert in his particular part of the great process, never seeing the finished product, but ever toiling bravely under the motto, "Each for all, and all for each." While he made cloth for his brother, his brother made shoes for him; and with those brothers who needed what he made and made nothing in return he exchanged his wares for some service he himself had no time to perform — the lighthouse keeper who made it possible that the merchandise he turned out might be shipped to its destination with safety, the fisherman who brought him food, the miner whose coal kept him warm.

It is to this band of toilers that we are indebted for the many comforts which we so unthinkingly accept. A thousand hands move ceaselessly that we may have food, clothing, and shelter; and as these men labor they create the products which are the chief source of the wealth of our great land. For America's prosperity comes not alone through the riches of her forests, mines, and fields, but through the toil of those millions of patient workers who convert raw materials into the perfected product which are the fruit of our modern manufacture.

FISHERIES

FISHING is a sport that never grows old. From the time the boy dangles a bent pin from the end of a cotton string to the time he weighs the respective merits of the "Doctor" or "Scarlet Hackle," its charm never weakens. Surmounting every failure is the chance for future success, and in this elusiveness lies the universal lure. But fishing as a sport and fishing as a means of livelihood are two very different things. In early days, man turned naturally to fishing and hunting as his chief defenses against hunger. Gradually his crude equipment gave place to the improved tackle devised by modern ingenuity. He learned, too, what fish frequented sea and stream; when the best season was to capture them; what bait was most successful; and to what uses his catch could be turned when hauled in. Fishing, in short, became an industry. Certain branches of it were followed by one set of men, certain branches by another. Cod, salmon, herring, and deep-sea fishing, as well as the trade in scallops, clams, lobsters, and crabs, were all taken up by men skilled in their particular craft.

COD FISHING

Along the eastern coast of North America, for instance, are hundreds of men whose livelihood is entirely dependent on the perilous occupation of cod fishing. Soon after the sealing season closes in April, fleets of small vessels make their way to the neutral waters off the Grand Banks of Newfoundland. Many of these schooners come from Canada, many from Maine and Massachusetts coasts, some from France, and some even from Holland. Often in the season there are as many as seventy-five thousand schooners, cutters, and yawls anchored on the fishing grounds. Each ship carries six small dories which can put off alone, and in this feature of the occupation the great danger lies. Frequently sudden fog or darkness shuts down on the fleet and the dories lose their bearings, or are perhaps overtaken by storms and driven out to sea; sometimes the little bobbing cockleshell, top-heavy with a big catch, is swamped by a wave. Cod fishing is done either by a hand line, by trawl, or by gill-net. When done with a line the fishermen go out singly. Trawling, on the other hand, requires two men — one to scull the boat and one to handle the tackle. The trawls, marked with their owner's flag or color, are carefully set, and later dragged up by the buoy line. Usually from two to three hundred fish —

mostly cod — are found inside. Live capelin (a variety of smelt) or tiny cod are used as bait. After the trawls have been cleared and re-baited they are again sunk, being carried to the bottom by two small anchors. The gill-net, set with flag-bearing buoys, is to all appearances like the trawl; the nets, however, are set at different angles and are intended for catching cod after the line fishing of the year is at an end.

The cleaning and salting is generally done at night, after the catch has been put aboard the vessel; during a season when the haul is large the men sometimes work all night, changing their posture frequently that they may not drop asleep. Sometimes, however, a collecting ship, equipped with ice, goes about among the fleet, and, after taking the haul aboard, steams back to the market with it. When it is possible, the fishermen put in to shore, where the split, salted cod are dried in the sun on wooden stages.

Herring, one of the big catches of the New Brunswick, Maine, and Massachusetts coasts, are taken in weirs at night, and afterward brought to shore and dried and smoked in bronzed houses like those so frequently seen throughout the Nova Scotia country. The eastern coast of New England is rich too in mackerel, bluefish, swordfish, and sea-bass. From Cape Cod to the Delaware River there are numerous oyster beds, and during the winter months many scallops are taken from this region by means of dredges. Lobsters, clams, and crabs have also an important place in the fishing industry.

HOW SALMON ARE CAUGHT

On the western coast of North America, both in Canada and the United States, are extensive salmon fisheries. Great numbers of these fish each spring enter the Columbia and the Fraser rivers and Puget Sound, and amid the riot of the swollen waters make their way upstream, moving near the center of the current and keeping close to the surface. This fishing lasts about five months and is done chiefly with trap-nets or gill-nets strongly made to meet the great strength of the salmon. On shore the fish are dried and salted, or are sent away for canning.

OTHER FISH IN SALT WATERS

The South has its mullet grounds off Cedar Keys, Florida, where the season lasts from December to March. These fish are caught in great quantities in purse-seines, gill-nets, or trawls. The Gulf of Mexico is also the home of the red snapper, held in high favor by the Southerners, and caught with hand lines from dories. Instead of icing these fish, however, they are put in tanks constructed aboard the vessels and are kept alive until handed over to buyers. A great variety of smaller fish are caught off our shores, to say nothing of the trout, bass, perch, pickerel, and landlocked salmon tc be captured in our inland rivers and lakes. The United States Fish Commission has many stations where both fresh and salt water fish are hatched and shipped all over the country for the restocking and preservation of the fish industry.

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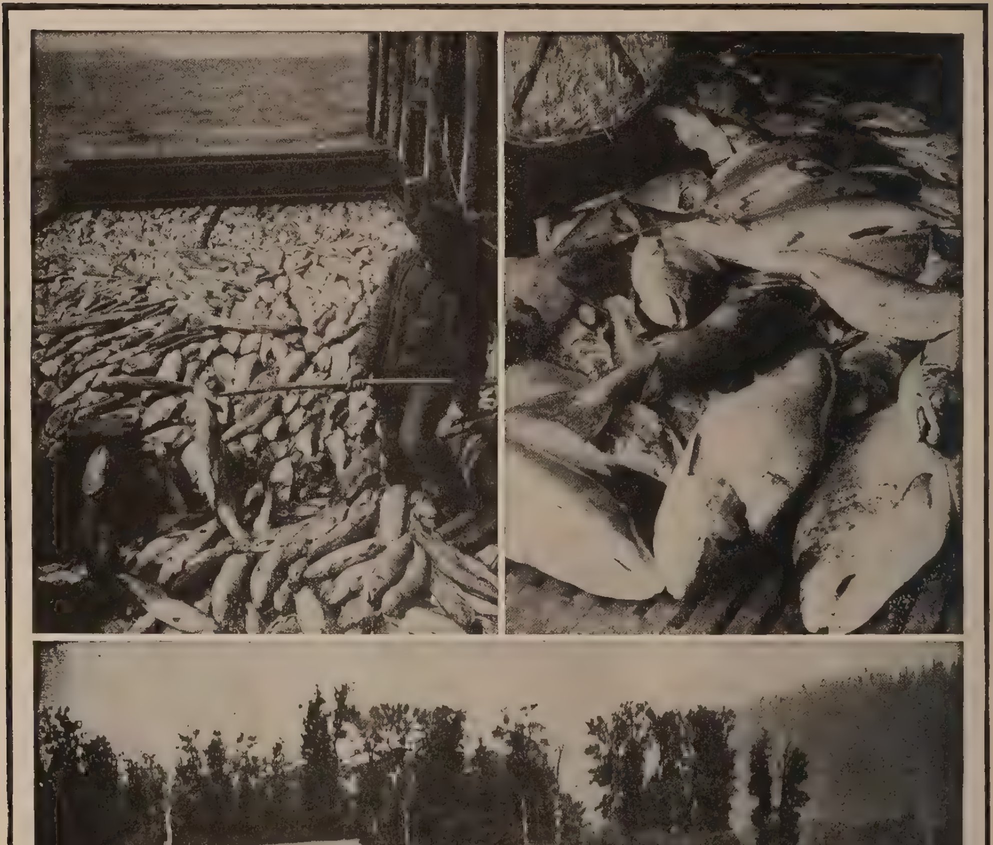
DRYING COD FROM THE GRAND BANKS AT GLOUCESTER, MASS., ONE OF THE MOST IMPORTANT FISHING PORTS AND MARKETS IN THE WORLD

A great number of the species of fish found off the American coast are also found in foreign waters. Norway has extensive salmon and lobster fisheries; England catches great numbers of herring and pilchard, a sort of gypsy



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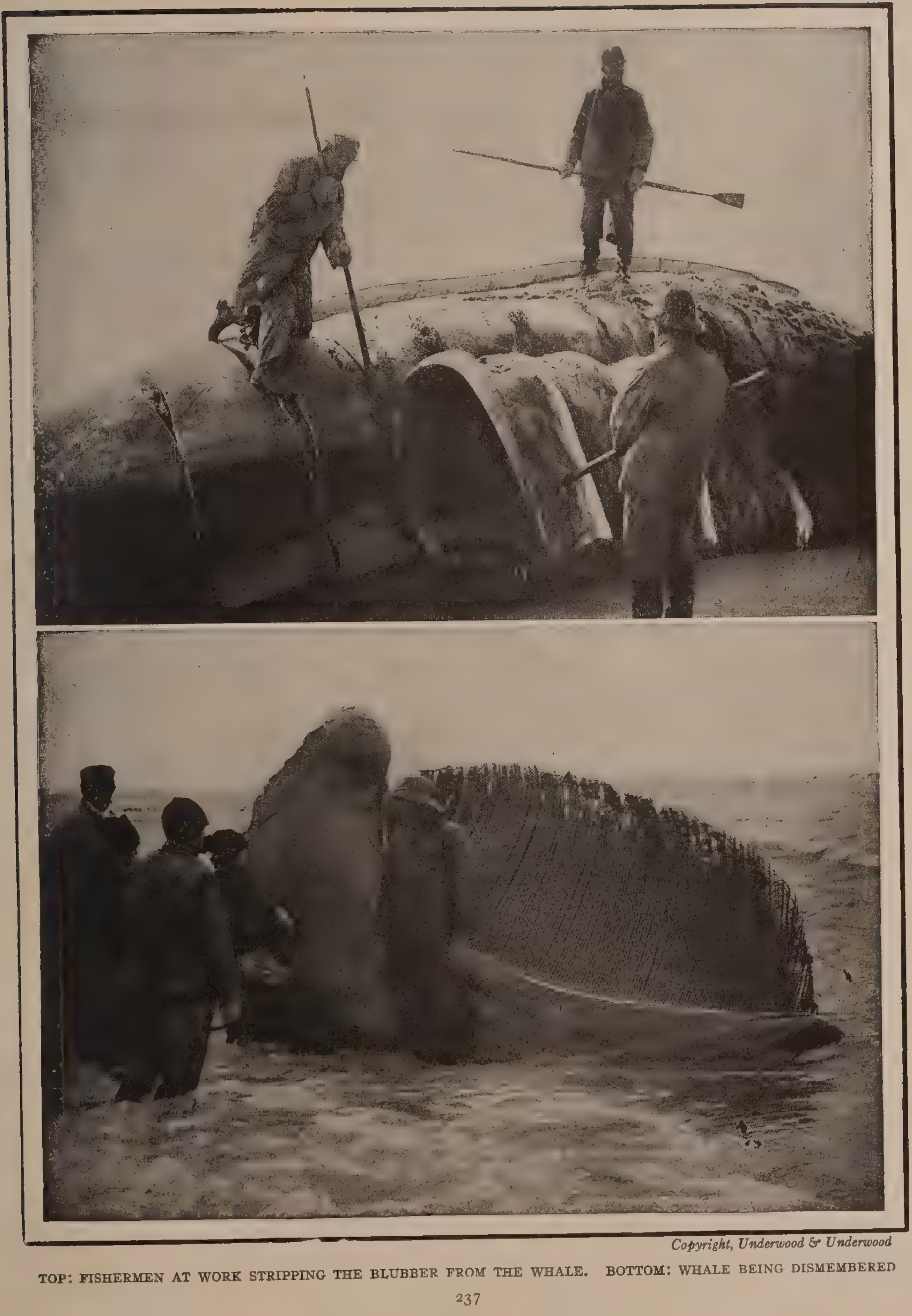
TOP, LEFT: SALMON BY THE TON STRAIGHT FROM THEIR NATIVE WATERS. RIGHT: SALMON ON THE FLOOR OF A GREAT CANNERY. BOTTOM: SEINING SALMON ON THE COLUMBIA RIVER, OREGON



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TOP: FISHERMEN AT WORK STRIPPING THE BLUBBER FROM THE WHALE. BOTTOM: WHALE BEING DISMEMBERED

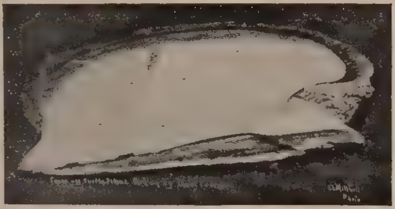
OYSTER FISHING. TONGERS FISHING FROM SIDE OF BOAT

herring, the smallest of which are shipped to Italy for the sardine trade. Sturgeon is found in England as well as off the North American and Russian coasts. The Mediterranean countries have vast anchovy fisheries as well as good catches of mullet and dory, the latter a gold-hued fish frequenting southern waters. Maigre, pilot-fish, sharks, saw-fish, and the tunny are all natives of the Mediterranean.

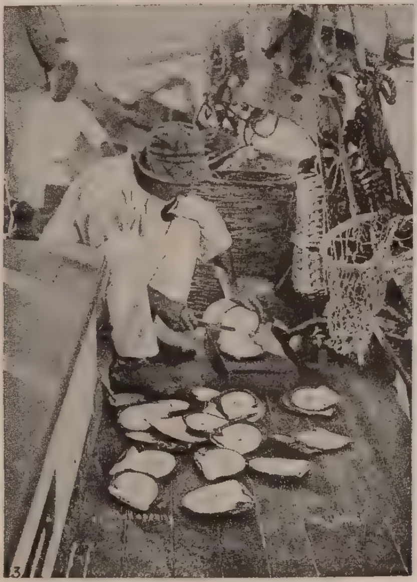
In China the fishing is frequently done by the aid of a cormorant, a bird accustomed to diving into the water for its food. These birds are taken when young and a tight metal band is put round their necks; to this collar a line is attached and the bird is trained to dive and deliver up his catch.

PEARL FISHING

The most important fisheries of the East are the pearl fisheries of Australia, New Guinea, Borneo, the Philippines, and Ceylon. The pearl fisheries of India, Ceylon, and the Persian Gulf are the oldest fisheries in existence. Here



Pearling is a great adventure and a great industry. The pearl is the only jewel which the sea produces. It is of great price and there is danger in seeking it. The shell, the mother-of-pearl, is what makes pearling pay. Pearls are found in only about five per cent of the shells recovered on any pearling ground. Pearlshells and pearls are found over vast tracts of tropic seas. In western Australia the industry flourishes all up the northwest coast. The diving dress is used now entirely. In early days naked aborigines did the diving: now it is a science of complicated mechanism and appliances.



SEEKING GEMS MADE BY IRRITATED OYSTERS

Top: Work of an irritated oyster bent on covering the organism annoying it. Pearls and shell ornaments. Center: Opening the oysters to find pearls. Bottom: Unloading shell from a typical pearl "lugger" or boat. A pearling fleet, high and dry at low tide.

are vast oyster beds, where seed pearls as well as the larger and more valuable gems are found. Pearls are formed by a bit of sand or other foreign matter lodging inside the oyster's shell. In order to protect itself from the roughness or discomfort of this object the oyster covers it with a fluid which soon coats it, grows larger, and hardens into a smooth pearl. Some of the flawless pearls found are of great size and value; others, imperfect on the outside, are discovered to be very beautiful when the outer layer is peeled off. On the other hand, some pearls have slight flaws, which become worse as the layers are removed. It is for this reason that the purchase of unpolished pearls is such a lottery. The demand for seed pearls is so great that there is seldom a large enough supply to fill it. Mother-of-pearl, obtained from the inside of the oyster shell, is also of great commercial importance.

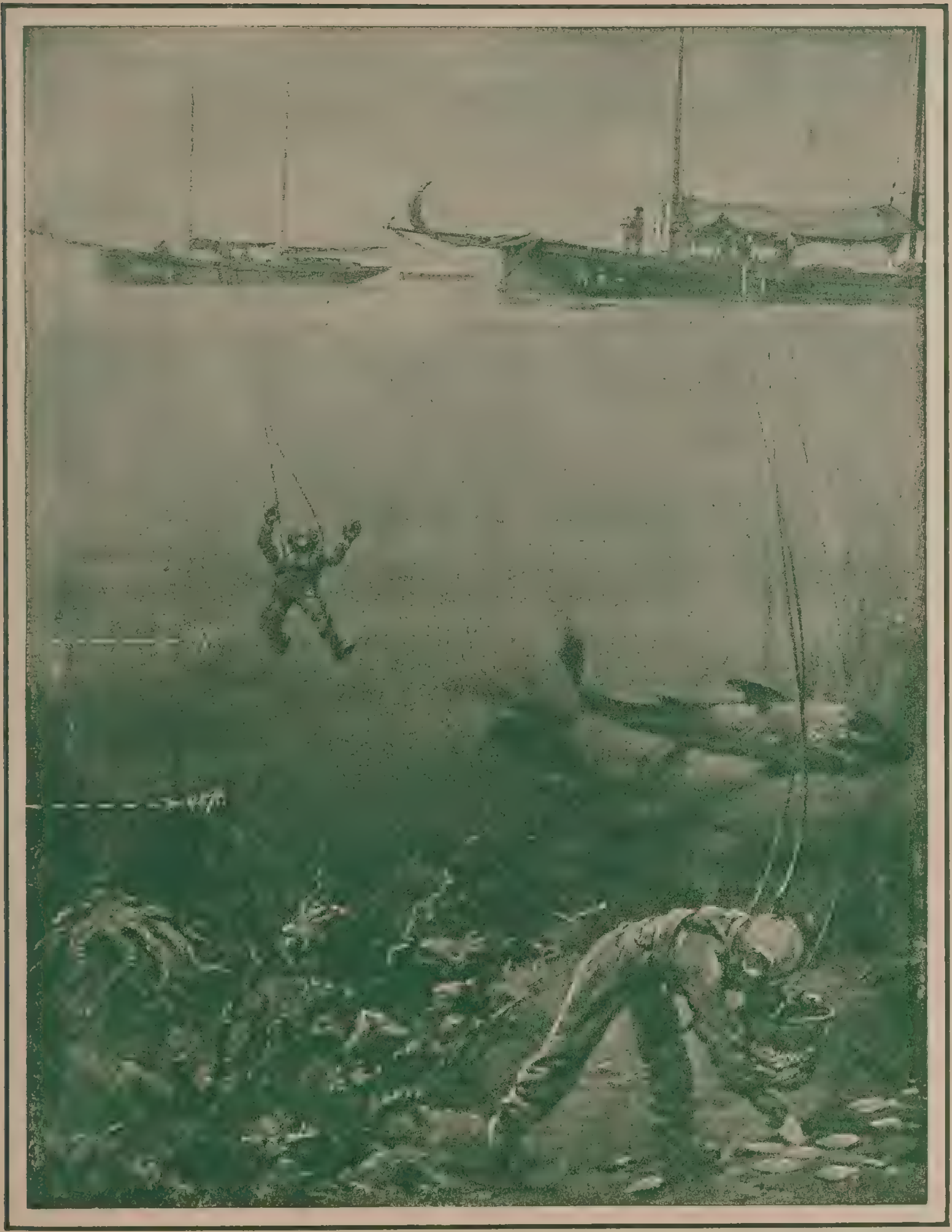
"MEASURING UP" THE OYSTERS IN A MERCHANT BOAT

Before a "fishery," the oyster beds are inspected to ascertain roughly the number of pearl oysters that may be taken; to mark the grounds on which fishing is to be allowed; to decide upon the number of boats to a given area and the length of time they can fish; and to estimate the probable value of the pearls, that the event may be advertised. Often a fishery will attract from thirty to fifty thousand persons. The boats put out soon after midnight, in order to be ready to begin work at dawn. Each boat carries its own divers. On reaching shore the load of oysters is sold to merchants or speculators who take the chance of finding valuable pearls in the cargo purchased. The oysters are opened under surveillance, and any loose pearls are taken out; afterward the fish are allowed to rot, when the débris is washed, drained off, and more closely examined.

SEAL AND WHALE FISHERIES

The seal fisheries of Greenland are frequented by the British, Americans, Dutch, Russians, Scandinavians, and Japanese, and an industry almost as extensive as whaling has been built up. The chief risk in this trade is the danger to vessels from floating ice. The seals are either harpooned and shot from the boats, or are clubbed to death on shore. The skin is then removed, and the blubber separated, ready to be boiled into oil.

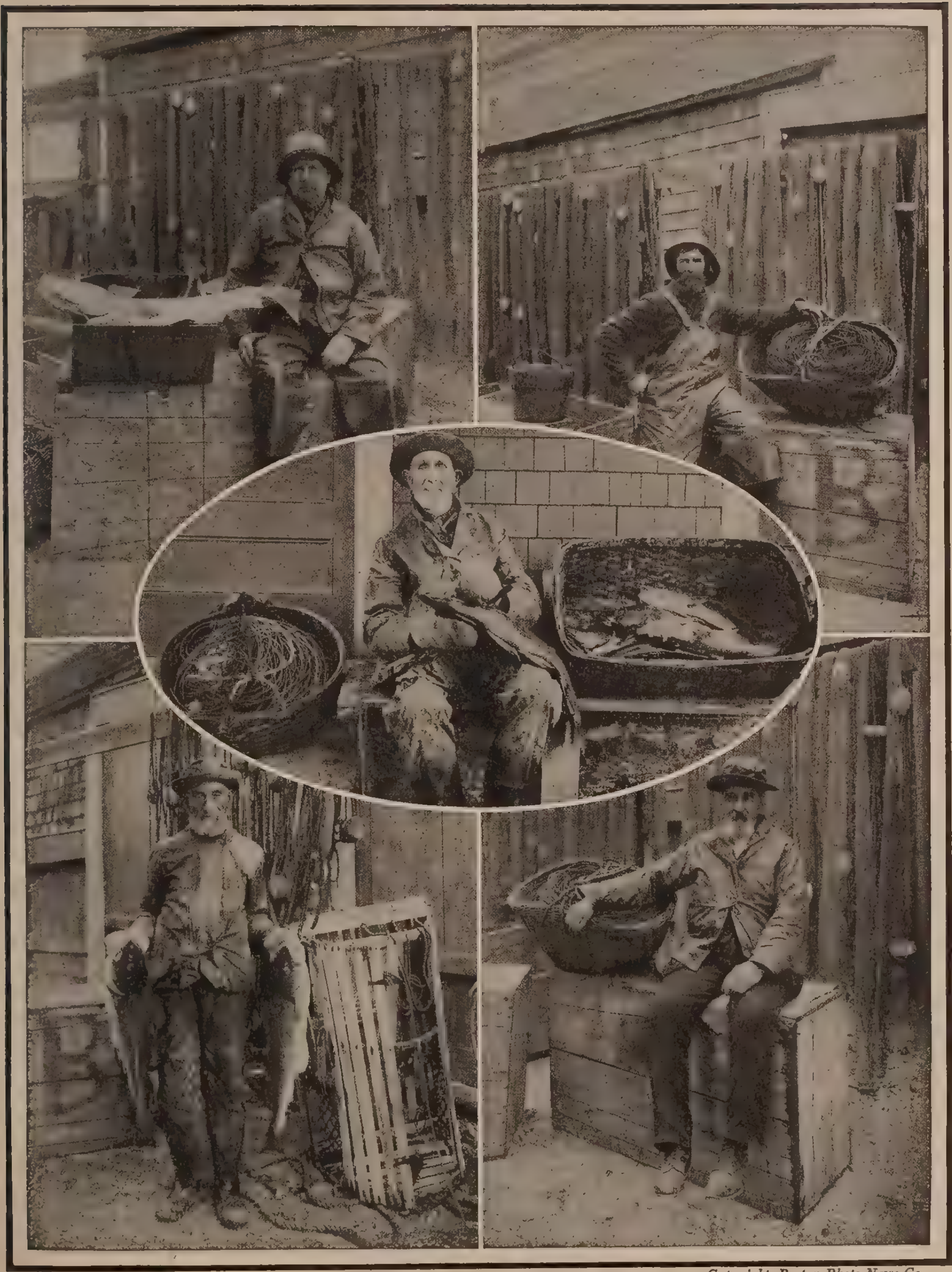
Whales, on the contrary, are seldom harpooned now as they were in the early days of the American "whaler." Instead we now have fine steam whaling vessels equipped with a crew of fifty, and carrying smaller boats, oil-tanks, windlasses, and all the conveniences necessary for the work. When the whale is sighted one of the small boats puts out, and a bomb-lance, or cast-iron tube filled with gunpowder, is fired. This lance penetrates the body and explodes inside it. The whale dives, comes up again farther off, struggles for a time, and weakens. It is then killed and immediately quartered so that the blubber can be boiled in the tanks, or, if there are no tanks aboard the boat, the body is towed to shore. Sometimes, when there are more whales to capture, the body is inflated with air, forced into it from a pump, and is anchored with buoys until the ship can come back and attend to it. Almost every part of the whale is turned to some purpose. The blubber is made into oil; whalebone is taken from the toothless variety of whale, spermaceti comes from the head of the cachalot or sperm whale; and ambergris, the undigested food in the intestines, is used for perfumes. There are two classes of whale: the Arctic or right whale, and the cachalot or sperm whale.



Courtesy Illustrated London News.

SCIENTIFIC PEARLING IN WESTERN AUSTRALIAN WATERS

One diver is at work, and another is "fighting" the excess of nitrogen out of his body while on his ascent to the surface. Paralysis is the diver's greatest peril, and this is caused by taking him carelessly out of the sea. Before reaching the surface he is "staged," or held in suspense, until he has quickened the circulation by vigorous motions.



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A GROUP OF GLOUCESTER FISHERMEN

Captain Brackett, the central figure, is 94 years old, and is said to be the oldest fisherman in the United States.

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WHEAT THE LEADING AMERICAN INDUSTRY
The United States and Canada have the greatest wheat fields in the world

Courtesy International Harvester Co.

TITAN TRACTOR PULLING TEN PLOWS

OUR WEALTH IN WHEAT

MATCHING the wealth of the waters, from which men draw fish for their food, is the wealth of the boundless acres of open prairies where the grains of the earth grow in abundance. Food is one of the prime necessities of mankind. In the story of "Fisheries" we have described one of the simplest of food industries. Here we have animal food, abounding in the waters, and replenishing itself year after year with little or no cultivation. The fish are taken from the sea and dispatched quickly to the consuming public. Any processes which they undergo in preparation are chiefly to preserve them as they are, not to transform them into any more complicated product. In the story of the wheat fields we have a food industry depending on a plant instead of an animal product. This industry, too, has been pursued from prehistoric times; it, too, ministers to a basic human need. But here modern science and modern machinery have entered with a transforming hand. Wheat would be a valuable product under almost any conditions. It was valuable under the tillage of the early farmer who dug his land with a pointed stick, sowed his seed with a toss of his hand from the sack, covered it with a harrow, and then waited for the harvest, which he would reap with a sickle and thresh with a stick or flail. But if wheat was a precious product in those days, how much more precious is it now, when the yellow fields of a nation's wheat belt are watched as if they were so much fine gold, when the wheat crop of a country may spell its prosperity or financial depression until another harvest come, when wheat is an "international food" and the reports of its growth are the concern of governments and financiers? We shall do well to follow the story of this grain, which is the raw product of an industry toward which the eyes of all the world are turned. In this particular story we shall be concerned only with the wheat as a raw product, as a gift of the earth, although in a later chapter we shall trace it through a secondary industry, that of its transformation into flour. In this early section of our study of "Industries and Occupations" we are interested in the simpler products as they come direct from the waters, the land, or the storehouses of hidden treasure under the earth. In later chapters we deal with food products and commodities as they come in their prepared form to our markets and shops.

WHEAT IS A CEREAL GRAIN

Away back in the dawn of history man discovered that the seeds of the wild grasses which grew at his door were good to eat. So the wise husbandman refrained from eating in a given year all the seeds that came from the plants, and gathered some to keep until the next season, when he could plant them and have more

Courtesy International Harvester Co.

TRACTOR PULLING BINDERS

grasses and more seeds to eat. Year after year he tried out the different grasses, and found some, the wheat grasses, which suited well both his soil and his taste. So he cultivated them, and this was the beginning of the first wheat field.

The wheat plant as we know it has never been found growing wild. In every land where it prospers the wheat grass has been carefully tended by man. In the early days there may have been only one kind of wheat, but that time is far back of the reach of human history. Different kinds of soil, of climate, and of care have tended to produce different kinds of wheat. In our own day new varieties are being hunted out in every quarter of the globe and crossed with those varieties which we know, so that better, stronger wheat plants may be developed, some for the wetter climates, others for the drier, some for the winter months, others for the spring.

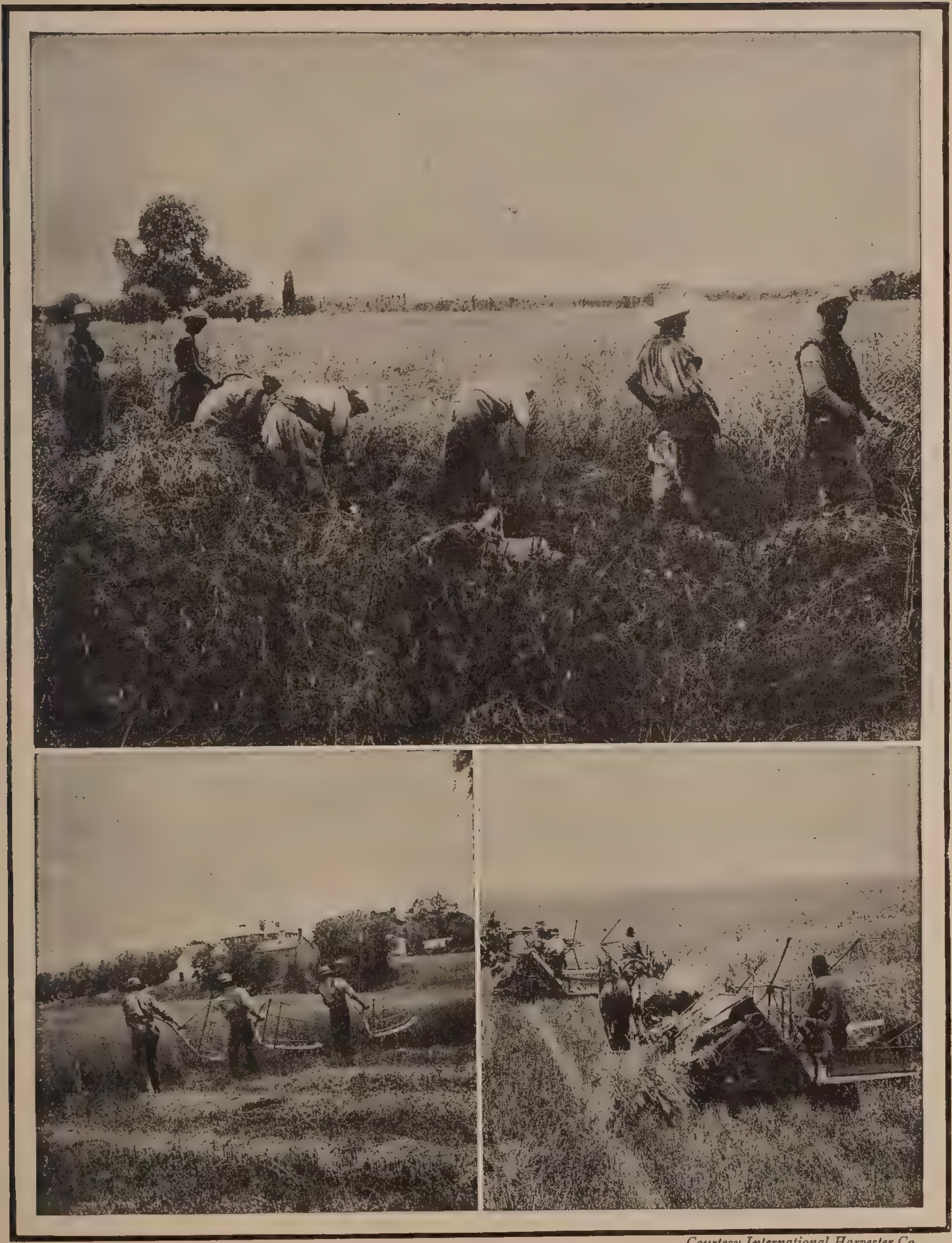
THE WORLD'S WHEAT BELT

If you could see a globe with a map of the world spread on it and the wheat belts of the world were shaded into a golden yellow, you would notice that the yellow areas were chiefly in the temperate latitudes, where the climate was moderate and the rainfall considerable. Wheat does not thrive in very hot or very cold regions. After the seed has been dropped into the fertile soil, the ground should be cool and moist. In such a soil the seed will germinate quickly and send out many stalks. When the grain is ripening, the weather should be warm and dry, so that the plants may mature quickly and fully.

Such conditions as these are most likely to be found in the temperate latitudes, on the prairies of the Middle West and the plains of Canada, on the steppes of Russia and the pampas of Argentina, in North Africa and Australia, above and below the equator in any region where the conditions of climate resemble for some period of the year those of our own temperate zone. Yet wheat is not limited to a single season. If the traveler will shape his course with this in mind, says one agricultural writer, he need not fail to find a ripened wheat field in any month of the year. "He may start in November in South Africa, proceed in December and January to Australia, cross the sea to India in February and March, and go on to Egypt in March or April. In May he can visit Algiers, in June Italy and Spain, in July and August central Europe, and in September and October he will discover the harvest

Courtesy International Harvester Co.

COMBINED HARVESTER AND THRESHER



Courtesy International Harvester Co.

TOP: THE OLDEST WAY OF HARVESTING — WITH THE REAPING HOOK, OR SICKLE, USED IN EGYPT B.C. 1400 OR 1500. BOTTOM; LEFT: AMERICAN CRADLE, INTRODUCED DURING THE LATTER PART OF THE EIGHTEENTH CENTURY. RIGHT: MODERN HARVESTING SCENE — A LONG LINE OF BINDERS SWEEPING THROUGH THE FIELDS

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TRACTORS PREPARING THE SOIL FOR WHEAT PLANTING

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A CORN HARVESTER AT WORK
Corn is the most valuable and the largest of our crops

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HUGE GRAIN ELEVATOR WITH WAITING FREIGHT, CHICAGO

in Scotland, Scandinavia, and Finland. Even in North America the harvest lasts from April, in Mexico, to September in Western Canada."

In the southern regions of the wheat belt, where the winters are not extreme, wheat may be planted in the fall sufficiently early to get a start before the winter season begins. Then it will be hardy enough to survive the winter and will begin to grow again in the early spring as soon as the frost has left the ground. This gives the earliest crop of our own continent, maturing in the late spring, and is called "winter wheat." Farther north the wheat will be planted as soon as the snow is gone, and will sprout and develop fast on the heels of the more southerly crop of winter wheat, following it with an interval of four or six weeks. So the planting and the harvesting of our great wheat fields goes on month after month as the seasons swing around. In the spring and summer months the transcontinental traveler will ride day after day across the great flat plains of the United States or Canada seeing only the acres of grain stretching away into the distance like the waters of the ocean. A map may indicate a wheat belt encircling the globe, but of the beauty and of the seeming infinity of these waving fields of grain, only one who has lived among them, or watched them day after day as they flowed past a swift-moving train that still seemed never to pass beyond them, can have any real conception. Not in the narrow confines of Wall Street but in the crops of the rich lands of the farmer, as they are tended by an army of sturdy workers, lies the real wealth of the United States.

The so-called "interior wheat belt" stretches across North Dakota, Kansas, Minnesota, Nebraska, South Dakota, Indiana, Illinois, Ohio, Oklahoma, and Missouri, and is matched by the wheat-producing states of the Pacific Coast, — California, Oregon, and Washington, — and the northern fields of Manitoba, Saskatchewan, and Alberta. Within these regions but in a narrower area lies the "corn belt," producing an almost equally important and even more abundant crop. Corn or maize is native to our country, and is one of the chief and most interesting of our American products. It cannot endure frost, and is therefore limited in its range to regions with a longer temperate climate, such as the prairie region of the Central States. Corn is the most valuable as well as the largest of our crops; we raise from three fourths to four fifths of the corn crop of the world.

WHEAT AS AN AMERICAN INDUSTRY

Both wheat and corn rank high as American industries. While we raise more corn than wheat, still wheat is usually reckoned the leading industry because so much of a corn crop is turned back as fodder for the raising of live stock, while wheat is perhaps man's most important food. Figures mean little when we are dealing with such immense quantities. The United States has the greatest wheat fields of the world; our crop is said to total about a quarter of the world's crop. Already the yield of wheat of a single year has run over a billion bushels.

The story of the machinery used in the wheat fields has been told in an earlier part of this volume in the account of inventions which have been epoch-making in our national and international life.[1] The soil is turned up by huge gang plows; the scattering of seed by hand gave place long ago to a distribution by modern machine seeders which may leave a seeded path a dozen feet or so wide; the huge harvesting machine, which cuts a swathe twenty, thirty, forty, or even fifty feet wide, may very likely be a thresher and a binder as well, so that the standing wheat in front of the machine comes out behind it in sacks of grain practically ready for transportation. There are small farms as well as large in our wheat states. There must be men to run these mammoth machines as well as men to follow the simpler methods of the smaller wheat grower. So there goes up in the season the cry for men and more men on the wheat fields, and an immense army of workers responds, — immense so far as the opinion of the onlooker would go, but never enough to satisfy the eager demands of the farmer for help in the harvesting of this quick and extremely important crop.

ONE OF THE ELEVATORS OF THE WASHBURN-CROSBY CO.

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LOADING LAKE STEAMER FROM GRAIN ELEVATOR, CHICAGO

GRAIN ELEVATORS

When the crop is harvested, there comes the next pressing demand. The wheat must be stored, first locally, and then in the great distributing centers, where it must be held until it can be shipped to its destinations for manufacturing or export. For this purpose there has been developed a special kind of building, known as a "grain elevator," equipped for receiving, storing, and discharging grain. These warehouses are located throughout the wheat areas, and are built in great numbers near the railway lines and wharves of the great distributing centers. They contain many floors over which grain may be spread to dry, or bins in which it is packed away from the air. Some grains, among them wheat, are better sealed and are therefore put in closed bins which open only at the bottom.

It has required no little thought to perfect the machinery used in transporting grain from ships and trains to the floors and bins of these warehouses. The unloading is generally done by elevators placed at intervals along a pier. The

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[1] See pages 95–101.

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TRAIN CROSSING NIAGARA RAPIDS ON STEEL SUSPENSION BRIDGE

Here we have a striking example of the essential part played by iron as the master metal of our modern civilization. Without iron we should have no locomotives, no cars, no rails, and no steel bridges; without iron, no ocean liners, and no airplanes, no huge office buildings, and no machinery for our factories. We live in the age of iron, and our nation is fortunate in its possession of enormous deposits of this precious metal, and of the fuel which is essential for its transformation into steel.

first one has a set of buckets which are let down into the hold of the vessel, where they scoop up the grain. These buckets are arranged on an endless band which passes over rollers at the top and bottom, and which hoists the grain forty or fifty feet. From seventy-five to one hundred and fifty tons can be carried from the ship's hold in an hour; it depends on the size of the buckets. After these buckets reach the top of the elevator they are emptied into a spout which carries the grain to a bin; here a second elevator lifts the grain still higher, and from this point it flows down of itself into weighing hoppers. As soon as two tons collect in these hoppers they are automatically emptied into still other bins and the grain goes then to the receiving elevators of the warehouse. Spouts afterward transfer it from these receiving elevators to the storage bins awaiting it. Here it remains until needed for the market, when it is either taken out and aired and then sent back to the bins, or is shot down shafts into wagons or vessels.

THE PNEUMATIC TUBE FOR UNLOADING

One objection to the bucket elevator in unloading ships is that unless the grain is directly beneath the hatchway it is very difficult to reach it. Therefore in recent years a flexible pneumatic tube has been invented which by air pressure sucks up the grain. This tube can be carried to any part of the ship. The moment a vessel docks this tube may be plunged into the grain and set to work. It is less awkward than the buckets and often accomplishes the task of unloading more speedily.

The grain-elevator business is a great one, and employs many thousands of men. Chicago, Buffalo, Duluth, and Omaha are among the large grain-shipping points.

IRON — THE MASTER METAL

THE importance of any raw product, and of the industries of which it is a basis, can best be estimated if we try to picture a world from which it has been completely and suddenly withdrawn. Without wheat a large part of the civilized world would soon be reduced to starvation; without iron the whole structure of our modern civilization would fall apart and crumble into ruin. It is startling to think how the fabric of our life is built on iron and steel. As we try to picture for a moment what even a shortage of iron production would mean, we find our railroads without rails on which cars could be run, without cars in which to transport men and goods, and without locomotives to pull those cars. We see our factories stripped of their machinery, our homes without their furnaces or stoves, our seas empty of their ships, our means of communication cut off by the absence of all wires, our workmen idle from the loss of their tools.

THE IRON AGE

It is thousands of years since man entered on the Iron Age of civilization, but only in the last century or half century has he learned to handle this metal in such a way as to gain its chief benefits. There was a time, as the arrowheads to be found in many parts of our country show, when man used stone for his tools and weapons. Then on some day, to be written forever as a red-letter day in the calendars of mankind, there flowed from a piece of rock which had fallen accidentally into a hot fire a molten metal. Perhaps iron had flowed out of rock many times before, but this time there was a man watching, a man with a mind to observe and a mind to invent, a man with hands which could fashion the picture in his mind. So before the molten iron from the piece of iron ore had grown cold, he shaped it, and as it hardened, it hardened in the shape of a tool or weapon. The Iron Age had begun. When did this happen? That it was long before the civilization recorded in the historical books of our Old Testament is evident to any reader of these chronicles. If you turn to the book of Numbers, in the chapters of the law concerning murderers (given near the end of the book), you will find that the first weapon suggested as likely to be in the hand of the man of violence is "an instrument of iron"; after it follow suggestions of "a stone in the hand" and "a weapon of wood." Turn a few pages, and in the early chapters of the Book of Deuteronomy you will find set down in the tales of the warfare of Og the king of Bashan the fact that this doughty warrior possessed "a bedstead of iron," and lest we doubt his ownership of so wonderful a treasure, not only its length and breadth are given but also its exact location in a neighboring village or town. Egypt, the land of captivity, is compared on the same page to "an iron furnace," while the land into which the Chosen People were to be led was "a good land, a land of brooks and water, of fountains and springs, flowing forth in valley and hills; *a land of wheat and barley*, . . . a land wherein thou shalt eat *bread without scarceness*, thou shalt not lack anything in it; *a land whose stones are iron*, and out of whose hills thou mayest dig copper." Hundreds upon hundreds of years have passed since those words were written; yet we of to-day might join hands with the ancient Hebrews in thankfulness for a land of wheat and barley, where we may eat bread without scarceness, a land whose stones are of iron and out of whose hills we dig copper.

FROM IRON ORE TO MOLTEN METAL

Iron was smelted by the Egyptians and by the Romans. It was looked upon with high favor by the warlike men of the Middle Ages, whose skill extended to the shaping in their forges of blades of steel. Kipling's old baron voiced the sentiment of many a man of his day when he declared iron to be the master metal. Others had come to him praising different metals.

> "Gold is for the mistress — silver for the maid —
> Copper for the craftsman cunning at his trade."
> "Good!" said the Baron, sitting in his hall,
> "But Iron — Cold Iron — is master of them all!"

"Cold Iron" it is, as man finds it, but not in free or pure form. Iron is said to form one-twentieth of the earth's crust; it exists everywhere in our rocks and soil. But it is only when it is found in rocks (or iron ore) in large quantities that it is possible or profitable to mine it. Here lies one source of our American prosperity, for our country is rich beyond most nations in the possession of this iron ore, and skillful beyond all others in its transformation into steel and the commodities of which steel is a part. The processes by which this rock taken out of the earth is transformed into steel will be described in detail in a later chapter. Here we are concerned not with the technical methods but with the industry as a whole. Before we enter into the story of ways and means it has seemed that we should take two of these basic industries of our nation and look at them in the large, seeing the wonder of what man has done and is doing with these raw materials which he finds in nature. Cold iron it is as man digs it from the earth, cold iron in combination with other substances. But before it can be of use to him it must be handled, as in the days of the Hebrews, the Egyptians, and the Romans, in a furnace. For the melting of this iron ore a vast amount of fuel is required, — two tons of fuel, as it has been estimated, to every ton of iron. Therefore the iron is not smelted in or near its native deposits. From our richest iron ranges near Lake Superior there is in the months of open transportation an unending line of vessels loaded with iron ore, passing through the Soo Canal and down the Great Lakes to ports which are near the great fuel centers of the United States, the coal deposits of Pennsylvania and neighboring states. For the wealth of a nation in iron must be matched by a similar wealth in fuel if the iron is to become valuable to mankind. Into the blast furnaces the iron ore is poured, with the alternate layers of coke or coal to maintain intense heat and of limestone to take up the impurities and hold them in combination until the molten iron has flowed out at the bottom of the furnaces. All that is described in the chapter on "The Making of Steel."

IRON IN COMBINATION

But what of this steel which we take so for granted in our daily lives, the making of which is a great basic industry in which hundreds and thousands of men are employed? Iron, molten iron or "pig iron," as it comes from the blast furnaces, could not be used in one one-hundredth of the ways in which it is now used. Here the knowledge of the chemist comes in. Iron in this state is ready to combine with other elements. Combined with carbon it forms steel, and the advantage of steel is that it is hard and flexible and strong. The sword makers of the Middle Ages went through the processes of steel making in their primitive form. But it has remained for the ironworkers of the last half of the nineteenth century and of the twentieth century so to manage and control the combination of iron with other elements as to produce a carefully graded series of iron compounds or alloys, each suited to some particular form of commodity.

Pig iron as it comes from the blast furnace is brittle; it is also impure, being not yet rid of all the substances with which it was combined in its original state. It is neither ductile, so that it may be drawn out or worked, nor malleable, so that it may be hammered. But brittle iron is useful for certain products, like the making of stoves. We have therefore blast furnaces turning out "cast iron," which is fusible and brittle. Another kind of commercial iron is "wrought iron," which is so treated as to remove the impurities but to add little carbon. It is a soft and easily worked iron, both malleable and ductile. Steel contains more carbon than wrought iron, less than cast iron. Nor is steel of a given and uniform hardness. Here also there are degrees according to the temperatures at which it is treated or the amounts of other matter added. There is the "soft steel," which is used for boiler plates; the "medium steel," with more carbon, used for building purposes; the "hard steel," used where great strength is required, for axles and shafts, or for tools.

"The value of iron," writes Slosson, "lies in its versatility. It is a dozen metals in one. It can be made hard or soft, brittle or malleable, tough or weak, resistant or flexible, elastic or pliant, magnetic or non-magnetic, more or less conductive to electricity, by slight changes of composition or mere differences of treatment." So the modern worker in iron has learned and is learning to make the combinations as he wants

DRAWING OFF MOLTEN METAL IN AN IRON FOUNDRY

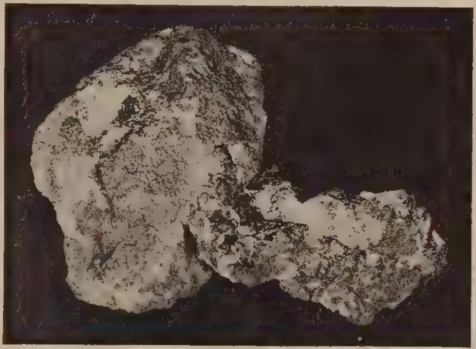
them. He does not confine himself to iron and carbon. Vanadium, tungsten, and dozens of other elements are used as the ingredients of this chemist's brew, and out from them come different kinds of steel, — one for watches and measuring instruments, another for the wires of our electric light bulbs, another for burglar-proof safes, and another for the armor plate of battleships. But underlying all is the basis of the master metal, iron.

IRON AS AN INDUSTRY

Iron is interesting as an industry in itself. From the iron mine to the blast furnace, from which the molten "pig iron" pours out, it gives employment to hundreds of workers. Its transportation is an industry in itself. But iron is most interesting as the basis of many other industries. The steel works of our nation give employment to thousands upon thousands of men. Let there be a labor shortage, or a threat of labor shortage, and the newspapers of the land are found discussing with all seriousness how this great basic industry may be manned so that its output may not be curtailed. Then from the steel works there reach out, like branches spreading from the trunk of a giant tree, the endless varieties of manufactures, small and large, which have for their basis the element steel.

WHAT AN INDUSTRY MEANS TO A NATION

The manufacturing side forms one part of the picture of an industry, the consuming side the other. On the one hand we have the vast army of workers engaged in the production of a raw product and of the finished articles of which it is the basis; on the other hand, the workers of the world — often the very same men and women — who use and depend upon the finished products of the industry. The steel worker is as dependent on steel in his daily life as are the rest of us. He depends also on those who are filling the ranks for the other industries. As the farmer relies on him for his tools and machines, so he looks to the farmer for his food. So from our story of these basic industries we get a knowledge of the importance of the daily activities of the workers of the world, and a sense of their interdependence. Robinson Crusoe on his island had to accomplish the feat of providing for the wants of his life without depending on others. In our modern world every act of our daily life, from the moment when we rise in the morning and eat a breakfast of which the ingredients have come from the ends of the world, until we return from our business and extinguish our lights for the night, involves a background of a thousand workers whom we have never seen and a thousand processes of manufacture of which we know little or nothing. Because of the tremendous interest of this world in the benefits of which we daily share, we are bringing to your attention in this volume some of the industries on which we depend for our daily life. We would have you better acquainted with the fisherman and the farmer, with the miner and the lumberman. We would have you regard the shoes on your feet and the rubber of your automobile tire, the glass and china on your table and the silk, cotton, and woolen with which you are clothed, with a new interest. We would have you know of the food products which come to you from afar; and, while you get a sense of the whole world as ministering to your needs, we would have you become a little more proud and a little more thankful for the wealth of your own native land, which is rich among all the nations of the earth in its natural resources and fortunate above them all in the citizens who make up its great industrial army.



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SPECIMEN OF ORE

In such form as this is the mineral wealth of our land, in iron, in copper, in silver, unearthed.

THE METHODS OF MINING

STOPE IN AN ORE MINE

SINCE the conveniences of our modern living are to such a great extent dependent upon mineral products, and since these products form such a vast part of the wealth of our country, is it not interesting to know something of how a mine is constructed and worked? There are many kinds of mines. Some are merely large mounds of ore which can be dug away with steam-shovels. Others are masses of mineral easily extracted after the layer of earth covering them has been removed; in mines like the South African gold mines, the metal comes in vertical reefs; most coal mines, on the contrary, have horizontal seams of mineralized vegetable matter running deep in the earth.

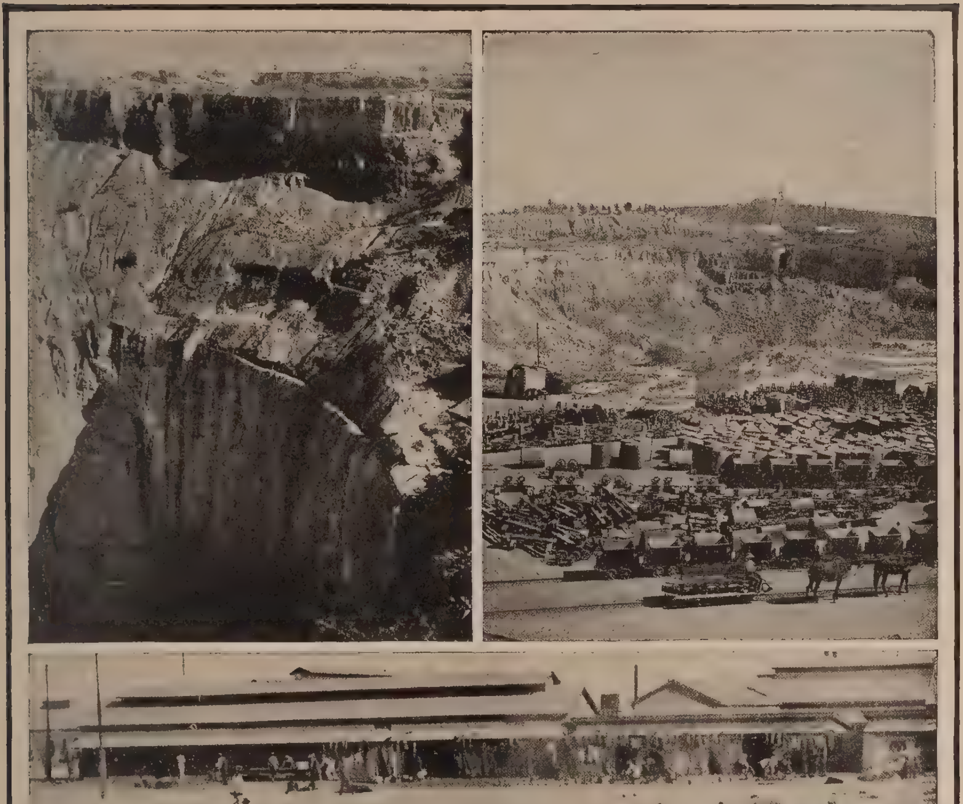
Courtesy, E. I. du Pont de Nemours Powder Co.

DRILLING THE BORE HOLES IN AN ORE MINE

MODERN MACHINERY

Mining machinery has revolutionized the methods, and justified itself by an improved product, and also by a reduced cost of production. The most significant proofs of this are to be found in the coal mines of this country. Steam and electric power are largely used in modern mining.

As the greater proportion of these mines are far below the surface, they are entered by a shaft, or vertical hole, sunk often to an enormous depth. For example, the main shaft of the Calumet



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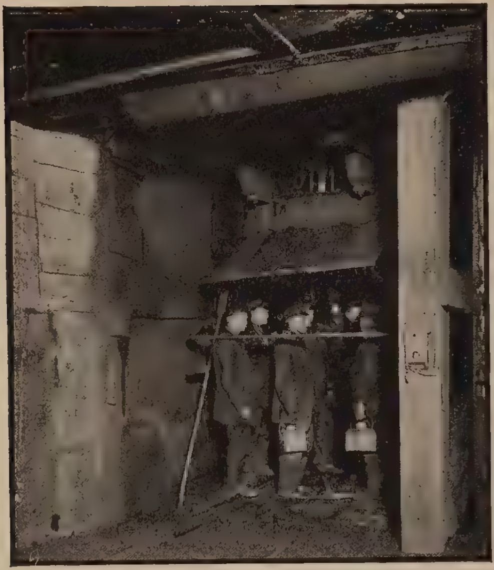
TOP: THE "GREAT HOLE" AT KIMBERLEY MINE, SOUTH AFRICA, AND PART OF THE WESSELTON DIAMOND MINE. IN THE FOREGROUND ARE MANY DISABLED TRUCKS. BOTTOM: THE COMPOUND, A LARGE, INCLOSED AREA, IN WHICH ARE CONFINED THE MINERS IN THE DE BEERS DIAMOND MINES AT KIMBERLEY



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MINERS ASCENDING FROM THE MINE IN CAGE

and Hecla copper mine is nearly a mile deep. The walls of these shafts are lined with wood, masonry or iron plate. More often masonry is used. Where the ground is hard and firm the shaft is rectangular, but if there is water in the soil or great pressure against it the stronger cylindrical shaft is constructed. A swift elevator, or miners' cage, for the transportation of passengers goes down this shaft. Generally there is another shaft for ventilation at a distant part of the mine. At present the up-to-date mine is ventilated by blowing fresh air into it by electric fans. From the main shaft the tunnels, or roads, branch out in every direction, and through them run tracks with cars, drawn by compressed-air engines, by electricity, or hauled by ropes or mules. The use of electricity has been of great value to the mining industry. The power is taken from some near-by stream and carried by pipes to a dynamo at the head of the shaft, from which it is run by cable down into the mine. It is employed to run the high-speed elevator, to provide power for hauling, to light the main passages, and to establish bell service from one part of the mine to another. It is a safe method too, possessing none of the objections found in most lighting.

One of the supreme dangers in the mine comes from the black-damp, or gas, which collects in all mines, and which explodes if brought into contact with fire. It is for this reason that the Davy lamp (see "Inventions") was such a great discovery. The miners wear these little lamps in their hats and they throw a circle of light about the men as they work.

DRILLING IN AN ARIZONA SILVER MINE

SKIDDING WITH OXEN, AND ROLLING LOGS INTO A STREAM

WHERE DOES OUR LUMBER COME FROM?[1]

IN the northwestern part of North America and in the northeastern and southern parts of the United States, as well as in the region of the Great Lakes, are mighty forests. White pine fringe the shores of the Lakes, while in the southern states quantities of yellow pine are found. Hardwoods, hickory, oak, and maple grow upon the lower slopes of the Appalachian Mountains and on the adjoining plateaus. The Rocky Mountain district furnishes chiefly bull pine, Engelmann's spruce, Lodgepole pine. From the states of the Pacific coast come redwood and bigwood. Canada is rich in pine, spruce, hemlock, elm, maple, hickory, basswood, and these woods are distributed very generally throughout the country, with the exception of the central prairie region, as far north as Alaska. Central America furnishes us with mahogany, cedar, logwood and Brazil wood. These trees supply us with lumber.

A LUMBER CAMP A BUSY WORLD

A well-conducted lumber camp is a busy world by itself. When a stretch of timber is bought or leased by an individual or company, the first things done are to locate the boundaries, explore the timber, select the best spots for the camps, and direct their building; pick the crews to work; hire horses; make contracts for machinery; and plan how to manage the forest, to get a good annual yield of timber.

CONSERVATION LAWS

Great care should be taken in making these plans. Many of the trees are located on mountain sides where their roots act as soil retainers and prevent landslides. Furthermore they shade the accumulations of snow not only on hillsides but also at the heads of streams, and if this shelter is removed the snows melt quickly, swell the streams, and cause destruction by freshets.

Another thing to be considered is that many trees — like the hemlock, for instance — will grow only in the shade of other trees, and if the large ones are cut off the new growth will not thrive. When timber land is cut clean over it lies useless for many years, as it takes a long time for another crop of trees to grow upon it. Intelligent managers understand that if they cut only a certain percentage of an area each year, or cut only the ripe trees growing in a given area, they will have a good crop of trees each year, for young trees will constantly be maturing. All these laws which govern careful cutting

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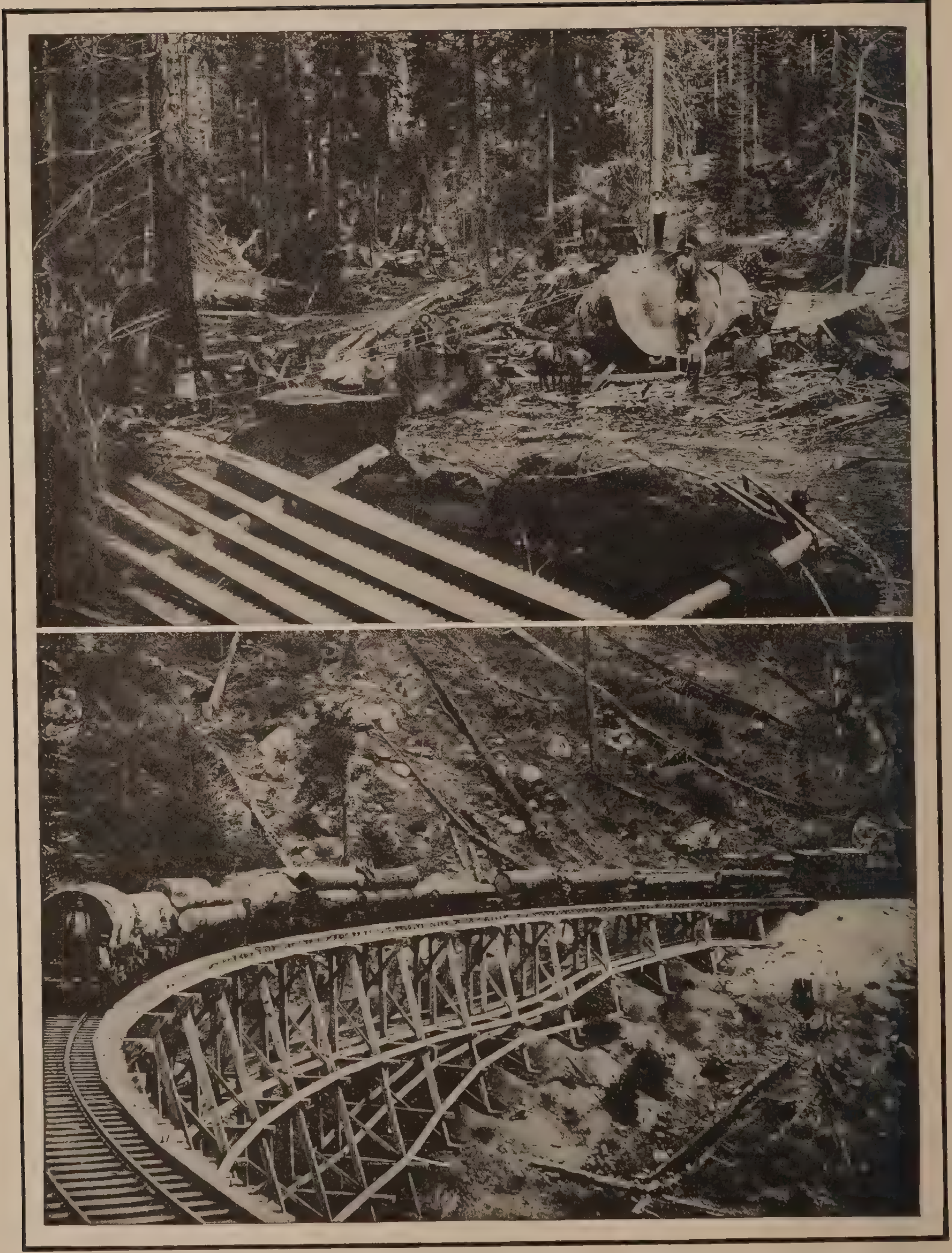
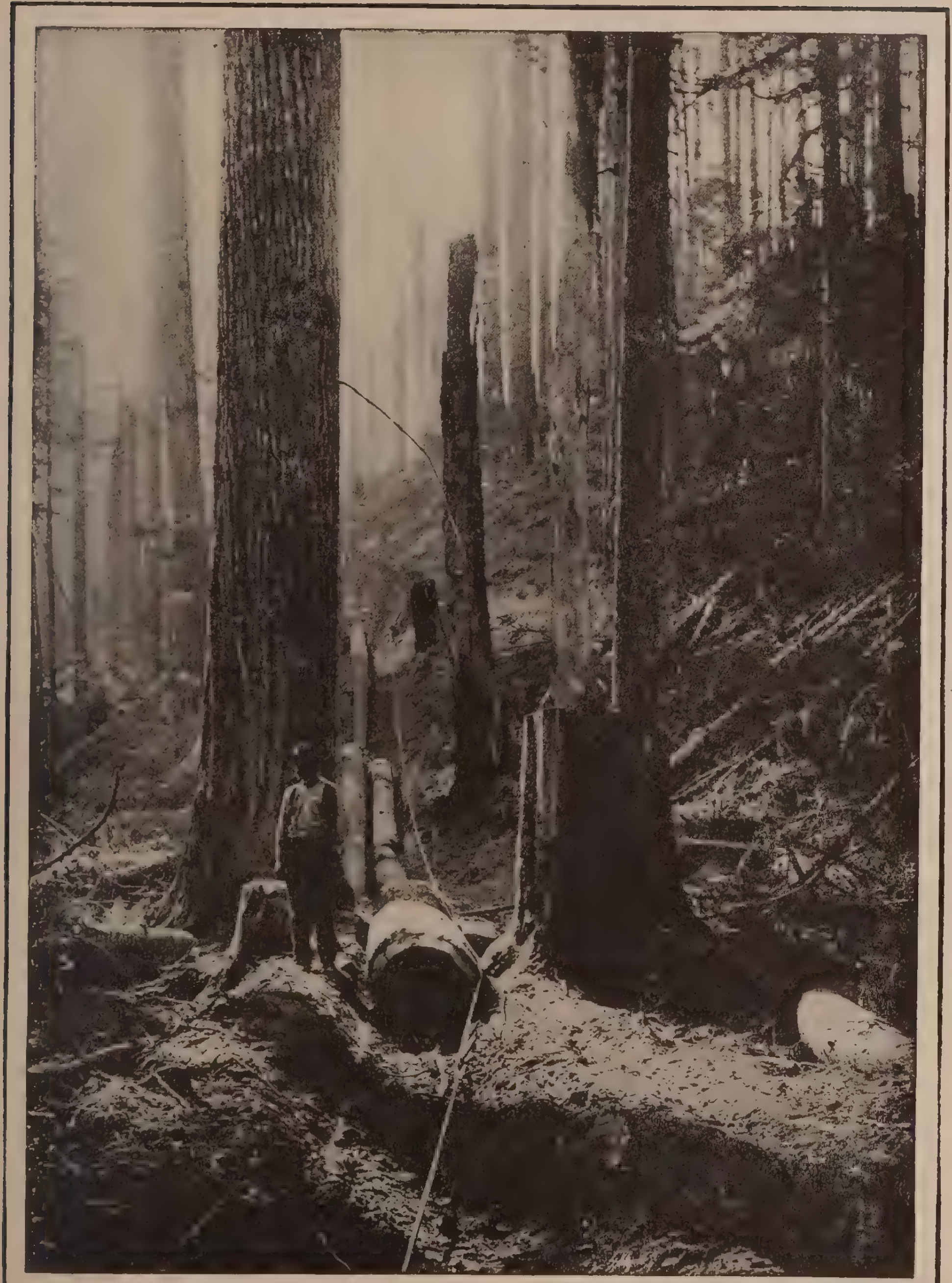
[1] The material for this article is taken from "The Story of Lumber," by Sara Ware Bassett, and is republished through the courtesy of the Penn Publishing Company of Philadelphia.



TOP: ROLLING A LOG ON TO THE TIMBER SLIDE, FRESNO CO., CALIFORNIA. BOTTOM: LOGGING RAILROAD IN A BIG-TREE FOREST, CALIFORNIA



HAULING LOGS BY STEEL CABLE, OREGON NATIONAL FOREST and not only foster finer forests but protect the surrounding country, are called Conservation Laws. The United States Government is still busy perfecting these laws, and they should be upheld by everyone who wishes well to our great country. Conservation means guarding what we have that its value may increase rather than diminish.

CAMP LIFE

Throughout the summer the lumbermen are employed in laying corduroy roads and marking the trees that are to be cut. When the snow comes cutting begins.

Roads are broken out and sprinkled each night so they may freeze and keep smooth and icy. When the sprinklers are started on their rounds late in the afternoon, they are filled with hot water, because cold water would congeal before the carts left the camps. Over these ice roads, or skids, heavy logs can be hauled with ease.

Every lumber camp has its blacksmiths, who spend all their time in welding chains for hauling, repairing tools, and mending the runners of sledges. Grindstones, too, whir constantly, sharpening axes and saws. In other sheds and lean-tos carpenters are at work fitting ax-handles of ash to gleaming blades.

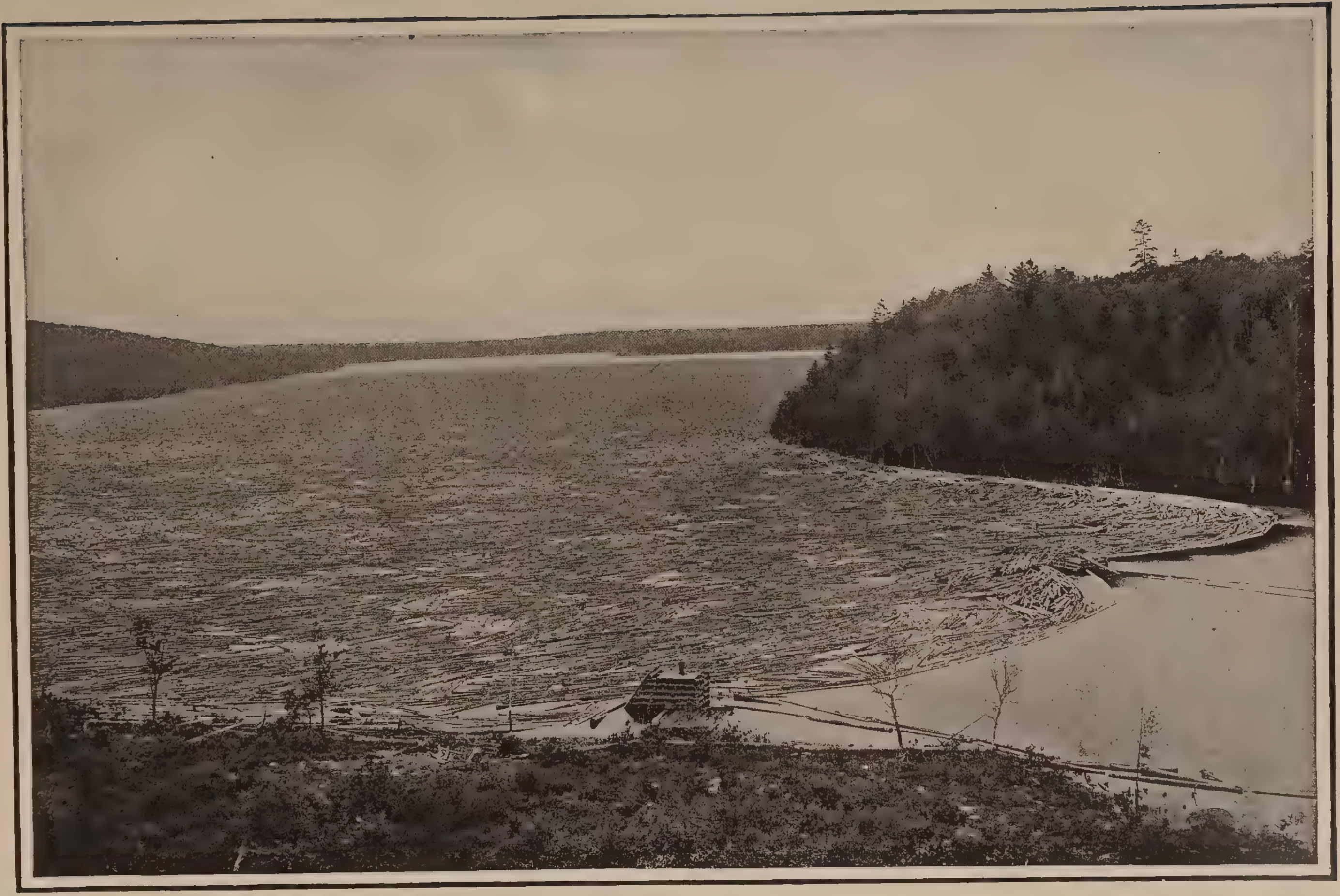
Every tree should be cut so that no stump is more than six inches higher than the tree is wide. This rule prevents waste. The fall of the tree is carefully calculated, so that when it crashes down it may do as little injury as possible to other trees and to the young growth near by. Good lumbermen will quickly release all the saplings that have been pinned down by the weight of falling timber. After the tree has fallen the branches are lopped off and carted away, either to be burned at the camps, to be used as soil retainers in repairing wood roads, or, if they chance to be balsam boughs, to be employed as bedding in the bunks at the camp. If these branches are not carried away a wise manager will insist that shoots on the under side of the branches be cleared off, that the branch may lie flat on the ground. It will thereby rot more quickly and become part of the forest floor. Nothing is more likely to cause forest fires than a litter of dry boughs on the ground.

When the timber is cut and stripped it is then hauled or skidded and piled where men with sledges can readily collect it and carry it to the margin of the lake or river near at hand. If lumber is cut on the shore of a lake a large boom or frame of logs fastened together by chains is made on the ice, and inside this boom the logs are placed. As soon as the ice melts in the spring this boom will drop into the lake and may then be towed across the lake to the dam, or sluice, so that the logs inside it will be ready to be driven downstream.

THE RIVERMEN

The journey of logs down a river to the mills is called a "drive." Log driving is both dangerous and exciting work. The men who drive the logs are called "rivermen." They wear slouch hats which will shade their eyes and at the same time stay firmly on their heads despite the wind. They also wear flannel shirts, trousers cut off at the knee, and long boots. Usually these boots have holes slashed in the toes to let out the water. Rivermen become very skillful in jumping from one slippery log to another; in retaining their balance when the logs move rapidly and crash into other logs; and in running the length of logs even when they are bobbing about in a seething current. Often the rivermen are waist-deep in water from dawn until dusk, for when the drive once starts it must be hurried along before the rivers, high with the spring floods, fall. Sometimes the weather turns cold so that the streams freeze again. Then the rivermen must go ahead and blast out the ice in order to keep the waters open. Frequently they are obliged to work all night to prevent the streams from freezing over.

Being in constant danger makes the rivermen a reckless crew. So often are they thrown into the water that unless they seem in real danger little attention is paid to their plight. They will float downstream clinging to the logs and clamber to their feet, smilingly drying their clothing in the air and sunshine as they continue on their way. An old and tried riverman is proud of his skill, and many a time when in midstream will cut up every sort of foolhardy caper for the delight of his companions.



A LAKE FULL OF LOGS

This vast collection of cut timber conveys a graphic idea of the scale on which lumbering is carried on in some parts of North America.

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SAWMILL IN BIG-TREE DISTRICTS, MILLWOOD, CALIFORNIA

The drive begins as early in the spring as the ice is out of the streams and is rushed along as rapidly as possible. The time required is dependent on the distance traveled and on the

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CUTTING A GIANT REDWOOD TREE

good luck experienced on the drive. Generally even a long drive will reach the mills by late spring or early summer. Driving crews come into the lumber camps late in the winter and from then on watch eagerly for signs of a thaw. Then the huge piles of logs along the river's edge are tumbled into the stream or "broken out," as it is called, and the sluice-gates at the foot of the lakes are lifted so that logs inside the booms may be turned out and hurried over the falls.

Crews of rivermen go ahead to direct the front of the drive, while others stay at the rear and send the logs along. The rivermen carry long poles having stout iron hooks in the end; these they use not only to urge the logs onward but also to help them to keep their balance. These poles are called "pick-poles" or "peaveys." Without them it would be impossible to keep the logs moving along in the current of the stream.

A JAM

One of the disasters a riverman most dreads is to have a block in the logs. This is called a "jam." Sometimes a log will become lodged upon a boulder or other obstruction, and before it can be freed other logs will pile up against it. The pile increases rapidly. Then the river crews must exert all their prowess to clear the jam. Not infrequently this can be done by finding the "key log" and dragging it out, thus loosening the entire heap. It takes the most courageous men to pick a jam in this way, for the moment the pile is free it sweeps down the river, often taking the rivermen along with it. When such dangerous work is necessary, the men are never compelled to do it. The man directing the work always calls for volunteers. Strangely enough more men usually beg to go than are needed. When it is impossible to free the jam, dynamite is used to blast it out.

After the logs reach their destination they are hauled on moving platforms into the sawmills along the shore and first stripped of bark. This bark is dried, packed, and shipped to tanneries. The slabs, or curved faces of the logs, are then cut off and utilized for shingles or laths. The slabs off, the square bolts of wood remaining are run into machines which grip them firmly and cut them into boards by means of bandsaws. Sometimes circular saws are used, but as these make a wider kerf or "bite," and are therefore more wasteful, the bandsaw is preferred.

The boards being cut, they are then taken to the lumber yards and piled crisscross in order that the air may find its way between the layers and dry them. This is called "seasoning" the lumber. Some boards are kiln-dried that they may not warp or crack when used in the interiors of buildings. Most lumber mills are so situated that they have easy access to railways or ships, by which their products are transported.

PAPER

THERE is scarcely a commodity of present-day civilization that answers so many purposes as does paper. Not only have we newspaper, wrapping-paper, books, and stationery, but we also have paper turned to scores of amazing ends, such as plates, towels, napkins, drinking cups, combs, and even locomotive wheels. Then, in addition, there are the multicolored tissue papers of every conceivable shade and design.

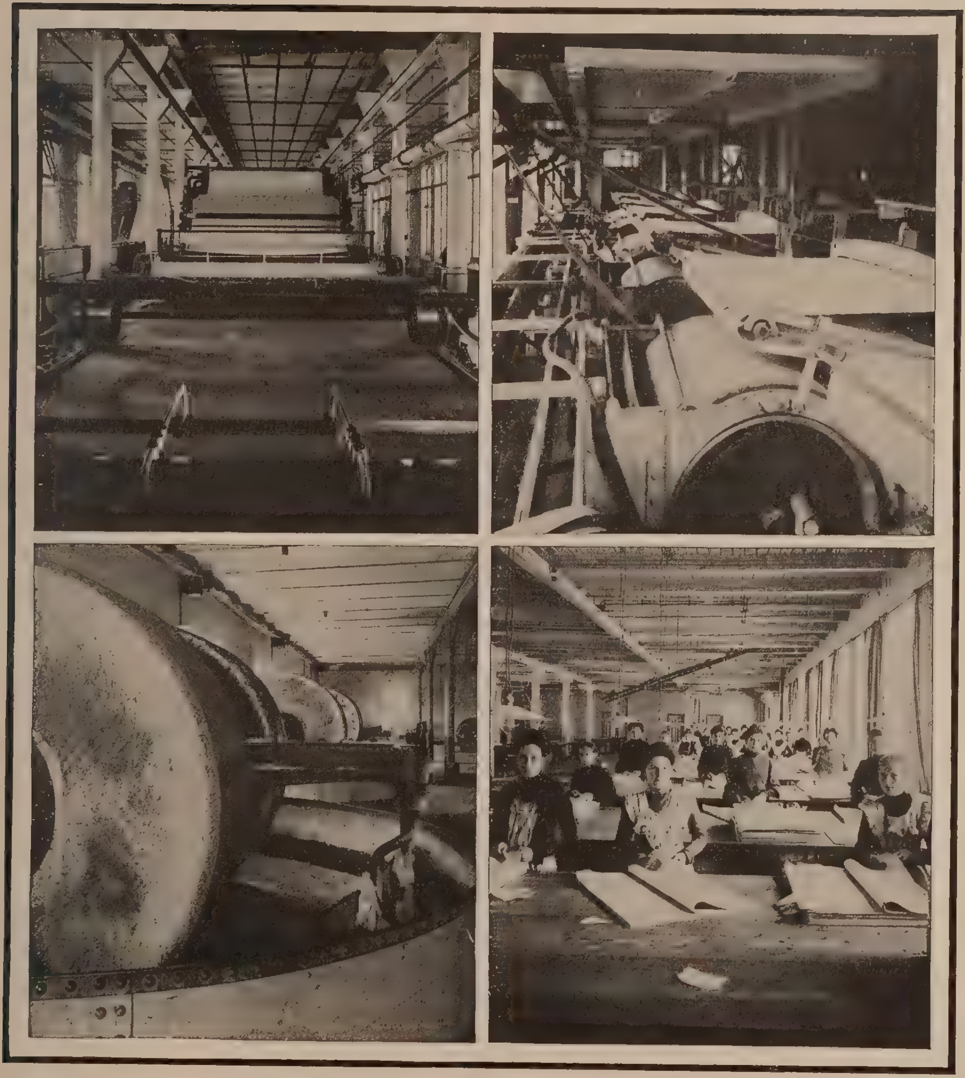
ORIGIN IN CHINA AND HOW IT BECAME KNOWN TO EUROPE

It is interesting to look backward to the days when the Babylonians wrote in hieroglyphics on brick, or the Egyptians scratched their messages on the ancient papyrus, the first primitive paper made from the pulp of the papyrus plant. Then came centuries when the Chinese and Japanese were the only paper-makers in the world, and when no one else knew there was such a thing until an Arab adventurer strayed into China and brought back the secret to the Moslem empire. It was a great discovery to the Arabs, who were scholars as well as warriors, and anxious to spread their religion throughout the world. For a long time, between the eighth and ninth centuries, Damascus was the great paper-making center. Then the Moors usurped the trade and kept

MAKING PAPER FROM WOOD. TOP: RUNNING LOGS FROM RAFTS TO SAWMILL, AND GRINDING BLOCKS INTO WOOD PULP. BOTTOM: SORTING MACHINES WHICH RECEIVE PULP FROM GRINDSTONES, AND "MIXERS" OF COLORS AND CHEMICALS WITH PULP FROM PULP CRUSHERS

it until they were driven out of Spain and the industry was swallowed up by the Spaniards. At first the Spaniards had no great luck with the new product, and while they were struggling with it the French mastered it, and about the thirteenth century took the first place at paper-making. Holland followed; and later, England, through her close contact with the Dutch, learned the art. Lastly America entered the field and at the present time is the greatest paper-making nation of the world.

The revolution caused when paper was first



MAKING PAPER FROM WOOD. TOP: PAPER MACHINE WHICH RECEIVES PULP FROM MIXERS, AND DRYING MACHINE WHICH RECEIVES PULP FROM SORTING MACHINE. BOTTOM: GRANITE CRUSHERS WHICH RECEIVE PULP FROM DRYING MACHINE, AND SORTING ROOM OF THE PAPER MILL

made can hardly be realized by one living in our day. At that time the masses of people were uneducated. There were no newspapers, and few books. What books there were were laboriously written by scholars or monks on bleached skins, or parchment, and illuminated by hand. An occasional traveler, or the minstrels who journeyed through the countryside or wandered from one castle to another, brought the news from the outer world; history and literature took the form of ballads which were chanted to the music of the harp. The minstrel, as you may well imagine, was welcome wherever he went; he was both the newspaper and the book of the day. People then liked stories quite as well as we like them now — perhaps even better; and since they had so few opportunities to gratify this craving they not only listened eagerly to the ballad singers but they painted all sorts of tales into their pictures and church windows, and wove stories of battle and adventure into their tapestries. Then hand in hand came the making of paper and the invention of printing (see "Inventions"); and the learning of the scholar, the lay of the minstrel, became the heritage of the world.

EARLY PAPER-MAKING AND HOW IT HAS IMPROVED

The first paper-making was done in very small quantities and entirely by hand. Manufacturers had not yet found out that it was possible to bleach colored rags with acids, as we do now, and use them for white paper; they thought that to make white paper they must use white rags. Cloth was expensive and so many white rags were hard to collect. In consequence little white paper was to be had. Instead there was a crude yellowish or grayish paper, and even that was costly. The method for making it contained, however, all the essentials of the processes followed to-day. Then, towards the end of the eighteenth century, Louis Robert, a clerk working in a French manufactory, came forward with his paper-making machine, which speedily took the place of hand processes and multiplied many times over the supply of paper that had previously been made. This machine is the basis of the elaborate devices used at present in our factories.

There was now no question of not being able to make enough paper; the sole problem was where to get the large supply of rags demanded. When, towards the middle of the nineteenth century, it was discovered that paper could be made from wood pulp, what a turmoil it caused in the industrial world! The fine grades of paper must still be manufactured from rags, it is true, but the cheaper kinds could be made from the fiber of poplar and spruce. Paper mills were rapidly removed from cities to the banks of streams, which not only provided power for running the machinery but rendered it possible to float logs down the rivers to the very doors of the mills. The most successful method for cutting up wood fiber has proved to be the grindstone. By this means the wood is ground fine and made into the pulp for our cheapest paper. Since, however, there is no long fiber in this pulp, the paper is weak and tears easily; for a stronger and better paper the wood is dissolved in acids, where the long fibers are softened and separated from the valueless part of the material. Often some wood fiber is blended in rag papers. Esparto grass is also dissolved and mixed in for other qualities of paper. The more rags and the less of other fiber, the finer and stronger is the quality of the material made. Paper of pure new rags is the best we have. Our greenbacks are made from new rags with bits of silk floss fed into the liquid pulp in order to give the paper strength and prevent counterfeiting.

HOW THE RAGS ARE PREPARED

When bales of rags arrive at the mills they are first put into openers, where they are pulled apart; they then go on to the beating machines, where much of the filth is thrashed out of them, and they are put into more fit condition to handle. Afterward the material is sorted — all buttons, hooks, etc., being taken off, and the rags shredded in small bits; later they are cut still finer by a chopper, and often large magnets are used to extract every remaining particle of metal. Then into great cone-shaped machines lined with spikes go the rags, and here they are torn, beaten, and cleansed, after which they are exposed to powerful blasts of air that blow out all dust and leave them in proper condition to be dissolved into pulp. This is done in giant boilers, where they are mixed with lime and soda and boiled from twelve to fifteen hours. The material is then dark and jellylike and must go into "hollanders," which wash it and at the same time separate the strong, valuable fiber from the soft, mushy part of the mixture. This fiber is drained off and put into beaters that work it into a pulp. Bluing is added to the bleached rags to give them a pure white tone, and sizing put in to give body. Some sizings are poor blends of mineral matter and chemicals, and the resulting papers are cheap and easily torn.

At this stage the pulp looks like a thin flour-paste. It is then poured upon fine wire frames through which the water is drained; the thickness of the paper is regulated by the amount of pulp poured on to the frame, and the width by the edges between which it is confined. The layers of felt, and the heavy cylinders between which it afterward travels, take out the moisture, dry it, and give it its finish. During these various processes it comes in contact with the "dandy roll"—a small, wire-covered cylinder—which leaves upon the paper the imprint woven in the wire. Sometimes this is a textile effect, sometimes the name of the firm manufacturing it; sometimes it is a symbol from which the paper takes its name. Most of the markings indicate the quality of the paper. In handling old and rare manuscripts these marks are often of great value in determining the date and genuineness of the curio.

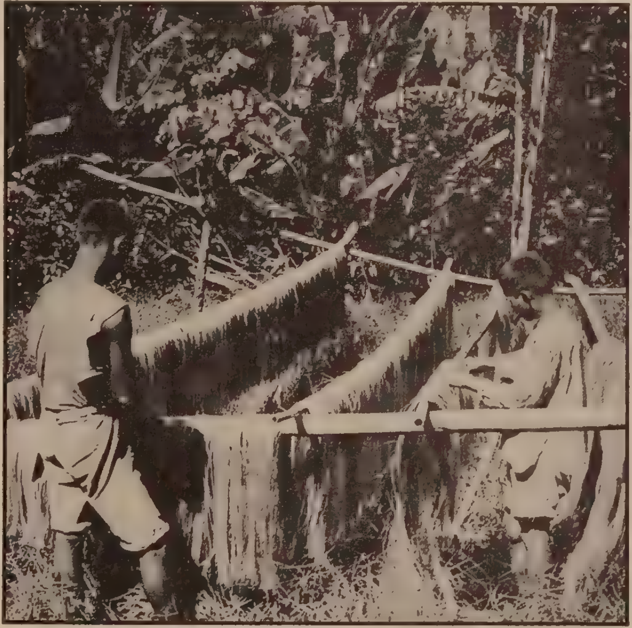
THE MANY KINDS OF PAPER

Ordinary newspaper is made, as has been said, from wood pulp; this is rolled out, and is delivered in rolls to the printer ready for the press. Book paper is "machine finished" — that is, it is in condition to use when taken from the machine. If a polish is demanded it is calendered. Most book paper, however, is without glaze, since for ordinary unillustrated books the glaze is not needed. Coated paper for illustrated magazines and books is brushed over with a coating which is frequently made from English clay and glue. All calendered paper is treated with a white sizing and then passed very quickly over hot rollers. The result is the same as that obtained when starching and ironing cloth — a high gloss is imparted to the material. Writing papers are made from mill ends or linen clippings, and given their various finishes in the "plating" or pressing.

* * *

ROPE, AND HOW IT IS MADE

THE modern method of making rope is an elaborate process and an industry largely dependent upon imported material. Although Kentucky and California furnish a limited supply of American hemp, the Philippines, Russia, Italy, and New Zealand provide most of the fiber consumed by American manufacture. This hemp comes from the fibrous portion of the stems of the plants. If a fine fiber is desired the plant is pulled up as soon as it has blossomed; if coarser fiber is required the hemp is allowed to grow until it has ma-



DRYING THE FIBER, PHILIPPINE ISLANDS

tured. In commerce the fiber takes its name from the country in which it was grown, as Russian hemp, Italian hemp, Manila hemp, and American hemp. The character of the plant and its fibers differs according to the conditions of the climate and soil in which it was produced. Manila hemp is far more widely used than any other. Italian hemp is finer, lighter colored, and stronger than American or Russian, and commands a higher price. With the exception of Manila, all these various hemps are a bast fiber—that is, they are obtained from the bark of the plant. The hemp is cut, spread out to dry, and then gathered and stacked in bundles. After a time these stacks are opened and the hemp is again spread out for exposure to dew, frost, and sun; during this rotting process the gums holding the filaments together rot, and the dry, inner, woody part of the stems breaks and falls off, leaving the fibrous strips or bands in such condition that they can readily be cleaned, bunched, and pressed into bales. American hemp is marketed chiefly for tarred goods.

INTERIOR OF NATIVE ROPE FACTORY, PHILIPPINE ISLANDS

Coir, another material used for making brown, tarred rope, comes from the fibrous bark of the cocoanut. Still another fiber employed in rope-making, and one ranking next in importance to Manila hemp, is sisal, which we get from the leaves of the Mexican cactus.

HOW SISAL GROWS AND IS PREPARED

Sisal plants are grown on large plantations known as "haciendas." The small shoots are set out in rows and weeded about twice a year. At the end of five years the first crop of long, swordlike leaves which mature at the base of the plant is ready to be cut, and from this time on until the cactus is twenty years old it continues to yield leaves for manufacture. At cutting time, natives armed with "corbas," or knives, go through the fields lopping off the long, prickly growth; the thorns are then trimmed from the edges and ends, and the leaves, tied in bundles of fifty each, are carried to the cleaning mill. Here the pulp is scraped from the fiber by powerful cleaning machines, and the fiber, after being dried in the sun, is pressed in 350-pound bales ready for shipping.

Since Manila and sisal are so much used, it is interesting to note that while Manila fiber ranges from six to ten feet in length, sisal measures from but two to four feet. The latter possesses only three fourths of the tensile strength of the former. Manila is famous for its smoothness and pliability; sisal is without flexibility and is much more stiff and harsh. This accounts for the unpleasant "splinters" found in sisal rope; their appearance in so-called Manila rope shows the use of sisal as an adulterant. Sisal is also more easily injured by exposure to moisture and varying atmospheric conditions. Sisal rope may be tarred, however, for out-of-door purposes, and the twine is in great demand for tying grain sacks and bales of cloth, and as a binder twine for the self-binding reapers now employed in grain-raising regions.

MANILA HEMP

For the ropemaker the most desirable raw material is "Manila hemp," which is really not hemp at all, but a fiber obtained from the wild banana plant of the Philippine Islands. This fiber is contained in the outer bark of the separate leaf stems, their inner portions being of a soft pulpy nature. After the stalk is cut the native peels off strips of this fibrous bark. After stripping the outer layer of stems, he scrapes off its remaining pulp and proceeds to strip the next inner layer. The fiber from the inner layers is finer and whiter than that from the outer. The fibrous strips are then cleaned by drawing them under a knife hinged over a block of wood.

After it is scraped the fiber is hung over bamboo poles to dry. When thoroughly dried it is tied up in hanks and carried to market. In the warehouses of the exporter it is sorted and graded, packed into bales, and shipped.

In consequence of varying conditions of climate and soil the hemp differs greatly in strength, texture, length, and color. Hence all shipments must be regraded before using. Frequently there are as many as seventy-five varieties in a single consignment, and this work must therefore be done by expert judges. After the fiber is sorted it is weighed, re-baled by a compressed-air engine, and marked and stored for future use. When taken out to be spun it is usually oiled to give it gloss and strength, and then combed so that its fibers will lie side by side. The hanks of fiber, somewhat matted from the oiling, are fed by hand into the first breaking machine, which turns them out in sliver form. This sliver is then reduced by other machines to the size required for spinning.

CUTTING SISAL LEAVES

LOADING SISAL LEAVES ON CAR

TARRED ROPE AND THE ROPE WALK

Tarred rope, associated in our minds almost entirely with shipping, is in reality turned to many other purposes. Lath yarn, in vast quantities, is annually consumed by the lumber industry. (See "Lumber.") Pine tar, best suited for cordage, comes from distilling in a tar kiln the pitch from the pines of northern Europe, or the long-leaf, yellow, or Georgia pines of the United States, found along the coast from North Carolina to Texas. When the tar comes from the kiln it is caught in a hole dug beneath the outlet, and is dipped up and poured into barrels. To penetrate and adhere to the yarn the tar must be heated to 200 degrees or over. The tarring is done in long, copper-lined troughs, where the temperature can be regulated by steam pipes. As the yarns, heavily saturated with tar, come

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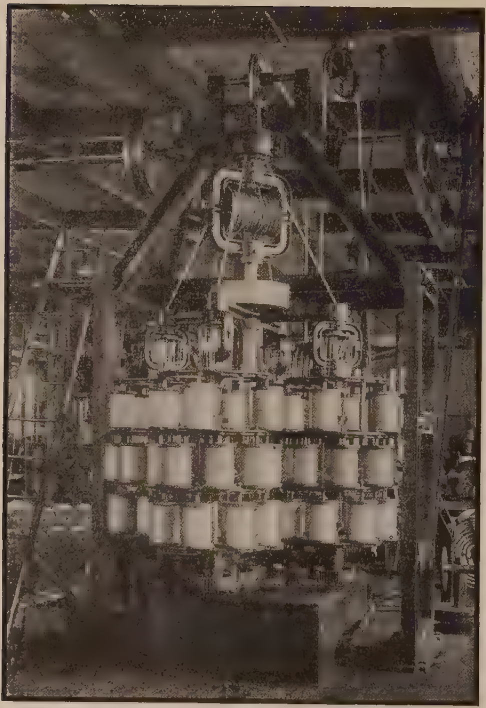

FOUR-STRAND COMPOUND LAYING MACHINE

from the "copper," they are compressed between two rollers, adjusted to leave in them as much or as little tar as is needed for the particular goods being made. The pull which carries them through the tar and the rollers comes from the drums around which the yarns travel preparatory to being reeled on friction-driven receiving bobbins.

In making tarred rope in all but the smaller sizes, the rope walk has certain advantages not offered by newer methods. It also provides efficient equipment for turning out the largest ropes, which would otherwise require special machinery. If you can get a chance to see this kind of rope-making you will have an interesting time watching the twisting of the strands, as well as the man who follows the machine and gives the name, the "rope walk."

Within the factory two methods of rope-making are employed: that in which the strands are formed on one type of machine and twisted into rope on another, and that in which both operations are performed on a single machine. Modern rope-making ingenuity, however, reaches its high-water mark in the compound laying machine, where the two operations of forming the strands and laying them into rope are combined; but since this machine must be stopped each time the supply of yarn on any bobbin is low, it would be impracticable for making the larger ropes.

Therefore, we see that by means of modern inventions rope-making has been transformed from a laborious task, dependent for its success on the skill of the individual expert, into a quick, sure operation where every problem is met with the unfailing accuracy of a perfect machine. The work is done more scientifically and more uniformly than it was in the days when it was strictly a hand process. When we consider the great amount of cordage required by the civilized world in the form of twine, cord, rope, hawser, or cable, the importance of this industry is apparent.

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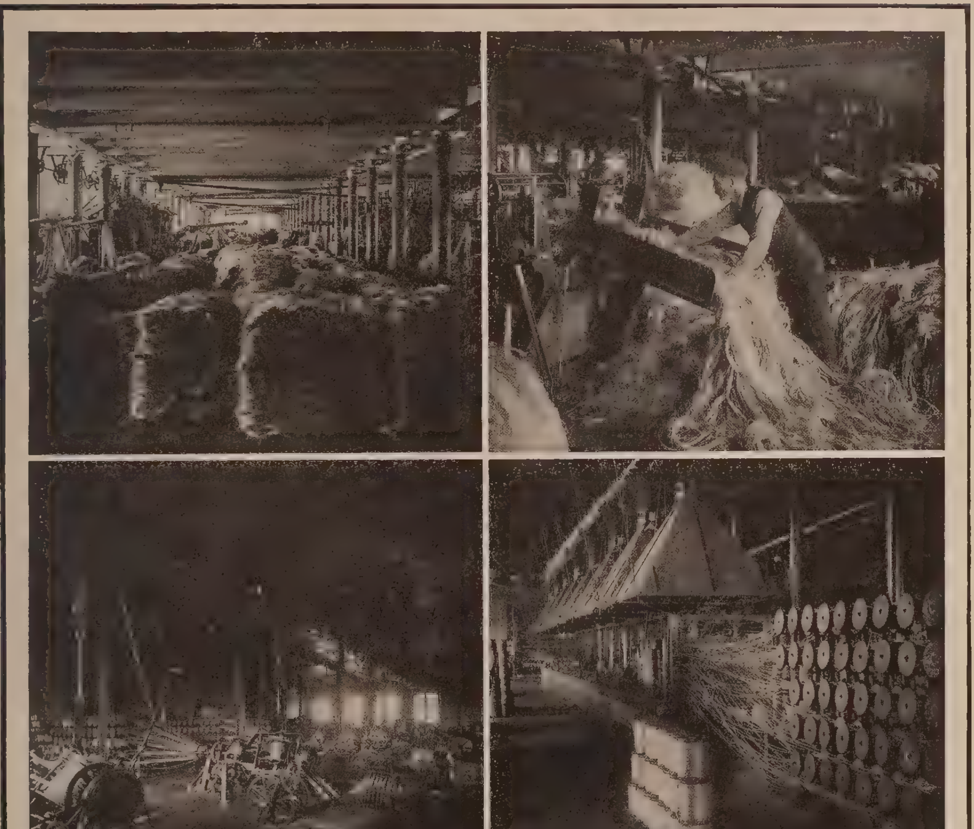
MEXICAN ROPE-MAKING



ROPE MANUFACTURE

Top: Preparation Room; forming the "sliver." Center: Yarn and rope rooms. Bottom: Winding tarred yarns, and closing Russian hemp 16-inch cable for Argentine battleship "Rivadavia."

PAINTS AND THEIR USES

PAINTING is one of the oldest as well as one of the newest arts. Early in the business of building their houses, bridges, and boats, men discovered that a surface covering of some oily liquid which would harden into a smooth outer coating would protect their handiwork from the ravages of sun, wind, and rain. So Noah covered his ark with pitch both without and within before he considered it ready for launching, and many a boat builder has followed his example. The modern aircraft manufacturer pays great attention to the coatings which will add strength and durability to the wings of his airplane or the body of his Zeppelin, and the automobile maker keeps a group of research chemists at work in the laboratory testing out the best enamel finishes for the surface of his cars. One large paint company is said to have between four and five thousand formulas or recipes for its paints, offering a variety of shades and types of liquid which is bewildering to the outsider. Yet there is a special use for every one of those paints, or the manufacturer would not be putting them out.

HOW ARE PAINTS MADE?

Our first thought of paint is of color. "What color shall we paint our house?" is the question asked at the family table, and long are the discussions of the relative merits of gray, white, yellow, or brown. It is only the father of the family who is thinking of the way that the paint will preserve the wood and so lengthen the life of the house. The obvious effect of paint is to give color to the surface on which it is placed.

Paints in ancient times were chiefly in natural colors. The Greeks, Romans, Assyrians, and Egyptians used the earth colors, reds from iron oxides, yellow ochers, mineral blues, and tints from lead and copper ores. Since oil was not so easily available then as it is in modern times, they found white of egg, or egg yolk, or some similar substance a convenient vehicle for carrying the color which they wished to spread on their outer and inner walls. The beautiful colorings on the walls of the houses of Pompeii and in the temples of Greece, Egypt, and the Orient testify to the skill of the artists who mixed the paints which have survived for so many hundreds of years.

"Prepared paints," as the dealers call them, are so popular nowadays that most of us have at some time opened a can of some shade of paint and gained some experience, as we used it, in the variety of kinds of paint and the "texture," so-called, of the different mixtures. All paints are made up of a liquid, called the "vehicle," and a coloring substance, called the "pigment." Since dry color powder could not be applied to a surface, the liquid gains its name of vehicle because it carries within it the color. In this particular it differs from a dye or a stain, both of which are color mixtures which are absorbed by the particles of the wood or cloth to which they are administered, so that they really enter into the material to which they are applied. Paints and varnishes are coverings, the only requirement being that they have enough adhesive liquid to hold them to the surface for which they are to form a coating.

To the mixture of liquid and coloring matter is often added some liquid which will thin the mixture, and also a "drier" which will speed up the process of forming from the thin, sticky substance a firm, hard coating.

MIXING PAINTS

Most of our paints are oil paints, in which the basis is linseed oil made from crushed flaxseed or some similar oil container from the vegetable kingdom. Our coloring matters are usually from the mineral kingdom. With the oil is mixed white lead, which is the standard white pigment. This coloring matter, usually in the form of a powder, lends body to the mixture as it dissolves in the oil. To this is added the coloring pigment which will give the desired tint to the final finish. Here the art of the chemist has made possible a great variety of shades, both from the rainbow of colors contained in coal tar, and from other mineral and earth ingredients. Since the paint must be spread with a brush, turpentine or some similar thinning liquid is added to this oil preparation, with red lead or sulphate of zinc for quick drying.

In the old days all this mixing was done by hand, and a good painter would spend many hours working over his paints to obtain just the right constituency and shade for the surface which he was to cover. The skill and good judgment of the painter are still important factors, but his labors are much simplified by the work that has been done for him in the factory. Here the oil and pigment are placed in a mixer and mechanically stirred for hours, so that the parts are perfectly blended. From the mixer they go to the grinder, where two huge mill-stones, revolving in opposite directions, smooth out every particle that might roughen the paint. Then the thinner and drier are added in carefully measured amounts according to the needs of each kind of paint, and lastly, if this is to be an enamel paint, varnish is added.

HOW DOES VARNISH DIFFER FROM PAINT?

Varnish is a transparent liquid. The grain of a hardwood floor will show through a coat of varnish, where a coat of paint would hide it entirely. Yet varnish is thicker and stickier than paint for it is made from a gum mixed with oil and therefore, when it hardens, gives a more shiny and brittle surface. We have all seen the drops of yellow resin or gum on a pine tree. Some varnishes are made from this pine resin, but they are of a cheap grade which grows sticky when exposed to heat. The best gums come from New Zealand and Africa where the natives dig them from the ground. They, too, are the hardened sap from trees, but they are hundreds and thousands of years old, the sap from forests long gone which has run into the ground and hardened. Natives find the small pieces and collect them until they have a pile to sell to the trader who comes for them.

Varnish making is even more difficult than paint making as the oil and the gums have to be heated separately and then mixed at exactly the right temperatures and cooked again over a very hot fire before the turpentine is added for thinning. Instead of the grinding process through which paint is put, varnishes must be filtered through hundreds of filter papers until they are thoroughly cleaned and strained of all impurities. Even then the mixture is not at its best but will improve with age.

Akin to varnishes, but with an alcohol or turpentine base instead of oil, are the lacquers which are so much used in the automobile industry. Shellacs have always given a pretty coating, but the film has been so thin that it was brittle and short-lived. By much experimenting the chemist has succeeded in producing a lacquer for metals giving brilliancy and gloss with a good amount of durability. Whole cars are dipped in these lacquers and sent out to the market with the fine finish with which we are all familiar.

LUMINOUS PAINTS

Radium and radioactive substances have introduced a new element into paints, making it possible for the instrument maker to coat his dials with a covering which will be self-lighting by night as well as light-reflecting by day. The convenience of this in the "radiolite" watch-face is obvious. Its real service comes on the dial board of a machine like the airplane where flying by night or in fog would be dangerous without constant visibility. With a self-lighting set of dials and clock-faces the aviator need only keep watch of his board to know his altitude and speed and the amounts of water, gasoline, etc. at his disposal. Zinc sulphide is one of the ingredients in these luminous paints.

PAINTS FOR PROTECTION

While all paints serve in some measure as a protective covering, there are places where this is the sole and only purpose of the coating which is applied. One of these is in protecting the bottoms of wooden ships from the ravages of marine borers and of metal vessels from the coatings of barnacles. A few barnacles on a rowboat do little harm. The summer sailor pays no attention to them. But when the bottom of a great vessel is covered with heavy layers of barnacles, the speed of that boat is greatly retarded and the fuel requirement for driving it through the water is much increased. Tests have been made of hundreds of colors and kinds of paint, and chemists have at last succeeded in finding "spirit paints," that is, paints with a vehicle of turpentine or alcohol rather than oil, of a light-colored, highly reflecting type which are unwelcome to the barnacles and make them seek elsewhere for a permanent abiding-place.

MATCHES

WHAT did man do before he had matches — for there was a time long ago when these tiny, indispensable articles were unknown, and when people were forced to resort to very primitive methods to make a fire. They first got flame by rubbing two dry sticks together until the sticks became hot enough to set fire to dried grass.

They then experimented further, cutting a hole in a piece of wood and turning a stick round in it so fast that it became hot and sent out flame. With this flame they were able to kindle some dry material if they worked quickly. Following this discovery came the striking of a metallic stone against a piece of flint, thereby making a spark which could be nursed into fire by touching it to some dried matter. How precious that spark must have been when one had to work so hard to get it!

This crude fire-making outfit was much improved later when iron and steel came into use, for then a metal box called a tinder-box was made to contain the flint; a piece of steel for striking the spark; and a bit of burnt cloth called tinder, that was used for catching the fire.

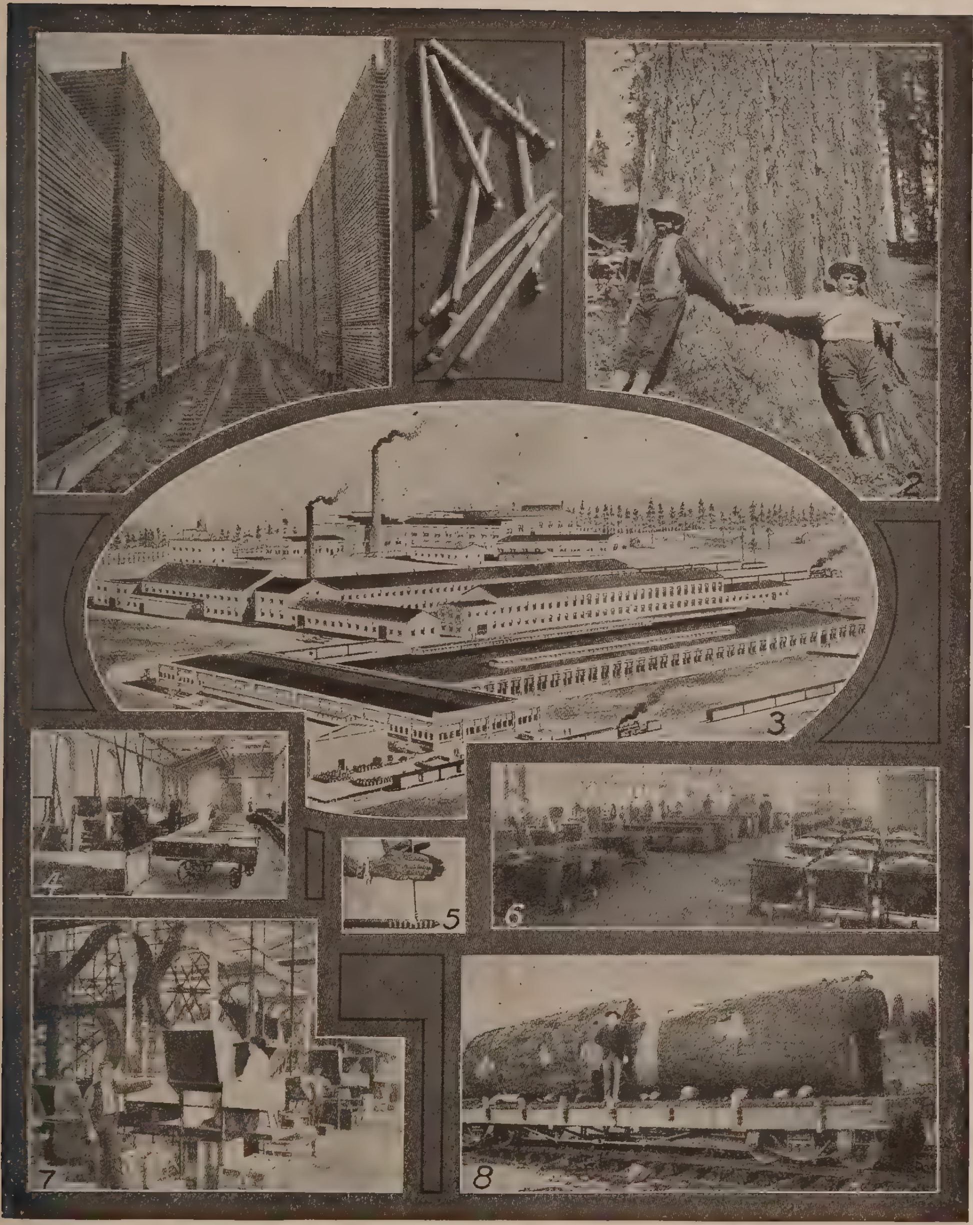
Still man felt there must be a more convenient and better way for creating flame. In 1805 a Frenchman made the first match that in any way resembled those we now use. It was a sort of match with a head made from many chemicals, and to light it the head must be dipped in a bottle of acid which immediately caused the chemicals to flare into flame. Of course it was very inconvenient always to be obliged to have the bottle of acid near at hand. It was a great stride forward, without doubt, but it did not satisfy everybody. Accordingly somebody tried another way; long tapers of paper with one end tipped with chemicals were made. Rolled away inside the end of the paper was a small bulb of thin glass filled with acid. To ignite the taper one must crush this wee bulb with pincers. This was better. It did away with the bottle of acid but in its place it left the pincers which must continually be carried about, and which were almost as much of a nuisance.

It was an Englishman by the name of Walker who invented the first match like ours, and even then it was not wholly like ours, for it lighted only when scraped between two layers of sandpaper. Yet it was far more convenient and less dangerous than to be dallying with a delicate glass bulb of strong acid that injured the hands if broken by accident.

All this experimenting covered many years. How strange it seems that it should take so long to perfect such a small thing!

Matches are now turned out in vast quantities, and instead of being costly — as they were in the early days — they are very cheap. We have the ordinary wood match and the wax taper; both are tipped with phosphorus, which makes them light. The yellow or white phosphorus first used for tipping matches (and, unfortunately, used to some extent at the present time) is very dangerous, being such a powerful poison that a grain of it will kill a man. Those who make matches are not infrequently poisoned by it, and every attempt is now being made to do away with its use. It is good that the United States has joined the ranks of more enlightened nations, which prohibit the use of poisonous phosphorus in the manufacture of matches. In place of this dangerous matter red phosphorus, which is not poisonous, is being used more and more. We see it on the *safety match*, which is rapidly crowding out other varieties. Not only is this match non-poisonous, but it is also more difficult to light, and therefore exposes people to less danger from fire. It was invented by two Frenchmen at the time the Belgian government offered a prize for a match to be made with no poisonous phosphorus in it.

Both wooden and wax matches are manufactured in much the same way. The narrow strips of wood are cut, split, and rounded off; then they are dipped and dried. Wax tapers, however, are a little less simple, for the cotton from which they are made must first be cleaned and then worked into strands of the required size. These long strands are afterward fed from large reels into a bath of melted wax. Here, after being coated, they are forced through holes in a metal plate and come out round, smooth, and just the right size. This done, the long waxed strands travel from drums, around which they are wound, to machines that clip them into short lengths the size of a match



HOW MATCHES ARE MADE BY THE MILLION

1. Lumber used for matches. 2. Large pine tree in match forest. 3. A match factory. 4. View in composition grinding room. 5. The old way of making fire. 6. View in composition mixing room. 7. General view of match machines which cut the matches, dip them in composition, and pack them in boxes. 8. Some of the giant logs on the way from forest to match factory.

and set them in frames with the ends of the taper up. Then comes the dipping.

On moving trays the matches are carried to the dipping-room, where a hot phosphorus mixture is awaiting them, poured out upon a slab. The heads of the tapers are pressed down into the mixture so that each match in the lot is tipped.

Drying these inflammable little things is dangerous work, for they will not dry unless they are put where it is dry and hot, and if they become too dry or too hot they will catch fire; to prevent a conflagration strong currents of air are constantly blown across them while they dry in the racks. When so dry that there is no chance of the heads sticking together, they are packed in boxes.

In both the "strike-anywhere" and the "strike-on-the-box-only" types of matches, the American chemist has shown great skill in providing a highly inflammable inner tip protected by an outer layer of material easily affected by friction. He has thus met the double requirement of quick results combined with a high degree of safety.

LEATHER AND ITS USES

COVERINGS for the feet were early recognized even by savage tribes as an essential to comfort. In some countries footgear originated in need of protection against burning sands or scorching stones; in other lands the cry was against cold or rough forest paths. Wood, fiber, or, best of all, leather, which the hunter or herdsman could make from the skin of animals, must be fitted to the shape of the foot in a way that would make for comfort and protection for the sole of the foot. The Indian fashioned his deerskin moccasins, decorating them with beads and porcupine quills; the Turk and Arab made gold-embroidered slippers of colored leather; the Chinese and Japanese had shoes of straw or satin; the Dutch wore wooden sabots; and the Eskimo fashioned fur-lined boots. There were heelless sandals; shoes with long, narrow toes which curved upward; shoes with jeweled or vermilion heels. Slowly from out this Babel of crude models was evolved the present-day shoe, which has proved to be the footwear best adapted to the conditions of life and climate in which most of us dwell; but in far-away lands orientals still cling, as we hope they will long continue to do, to their gold-embossed slippers and the Eskimo to his fur-lined boots.

There was a time, and it is not long past either, when cobblers at tiny benches laboriously made by hand all the shoes required by the civilized nations of the world. But like many another industry, machinery crowded out one part of the trade after another, and presently the old-fashioned shoemaker and his bench were displaced altogether. The making of shoes by machinery was a boon to mankind, for in a few hours more shoes could be turned out by these almost human devices than any hard-working shoemaker could finish in a year. In consequence of the new industrial conditions cheaper and better shoes came into the market — shoes far more comfortable, and representing the best thought of many minds.

HOW LEATHER IS PREPARED

Before the skin of any animal can be used as leather the hair, fur, or wool upon it must be removed, and the skin preserved so that it will not decay. This process is called "tanning." When skins are received at the factories they are always thoroughly salted to keep them from spoiling. Sometimes they are "green-salted," which means that they are salted and shipped as soon as stripped from the animal; sometimes they are "dry-hides," or dried without being salted, and as a result arrive at the tanneries stiff and hard; sometimes they are "dry-salted," or salted when freshly taken off, and then allowed to dry. All these skins, however, in no matter what condition, must be soaked in borax and water to cleanse and soften them.

Afterward they are thoroughly cleaned by hand, and all parts of them not useful for leather-making are taken off. This done, the hides are plunged into a bath of lime, sulphide or sodium, red arsenic, and hot water, which mixture loosens the hair so that it can easily be taken off. Sheepskins are not immersed in this bath because of the injury to the wool upon them; instead, the liquids are applied to the inside of the pelts, after which the wool can be pulled off without being wet. Such wool is called "pulled wool," and is sold to woolen mills.

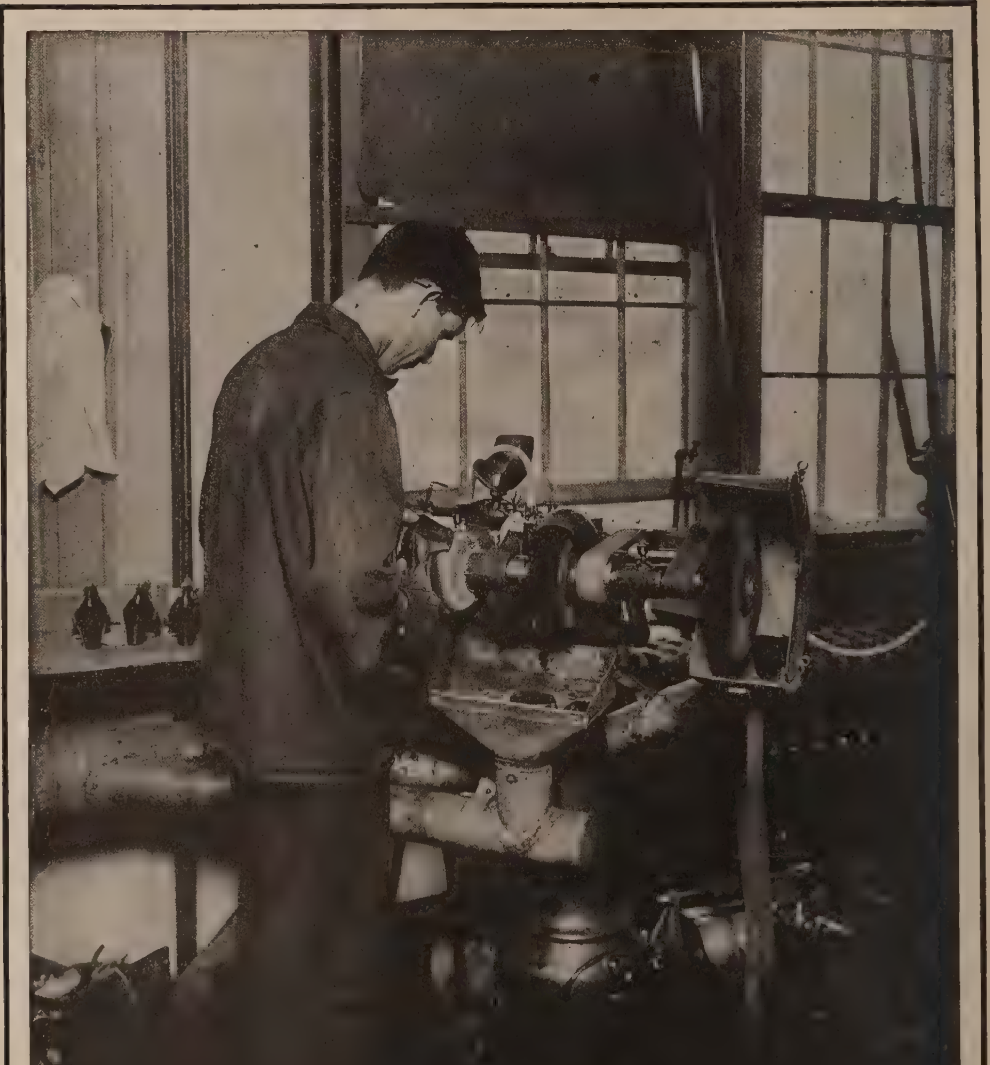
The "slat," or prepared skin, if heavy, is next split into two layers, and is then limed, after which the lime is washed out and the skin is "pickled" in a solution of salt, sulphuric acid, and water. Next comes the tanning, to give the hide strength and color. Two processes are used. The skins are either soaked in a vegetable liquid of water mixed with oak, hemlock, chestnut bark, sumac, palmetto roots, or quebracho, or are tanned with a blend of chemicals or "chromates." The process used depends upon the purpose and quality of the skin.

CUTTING OUT THE SHOES

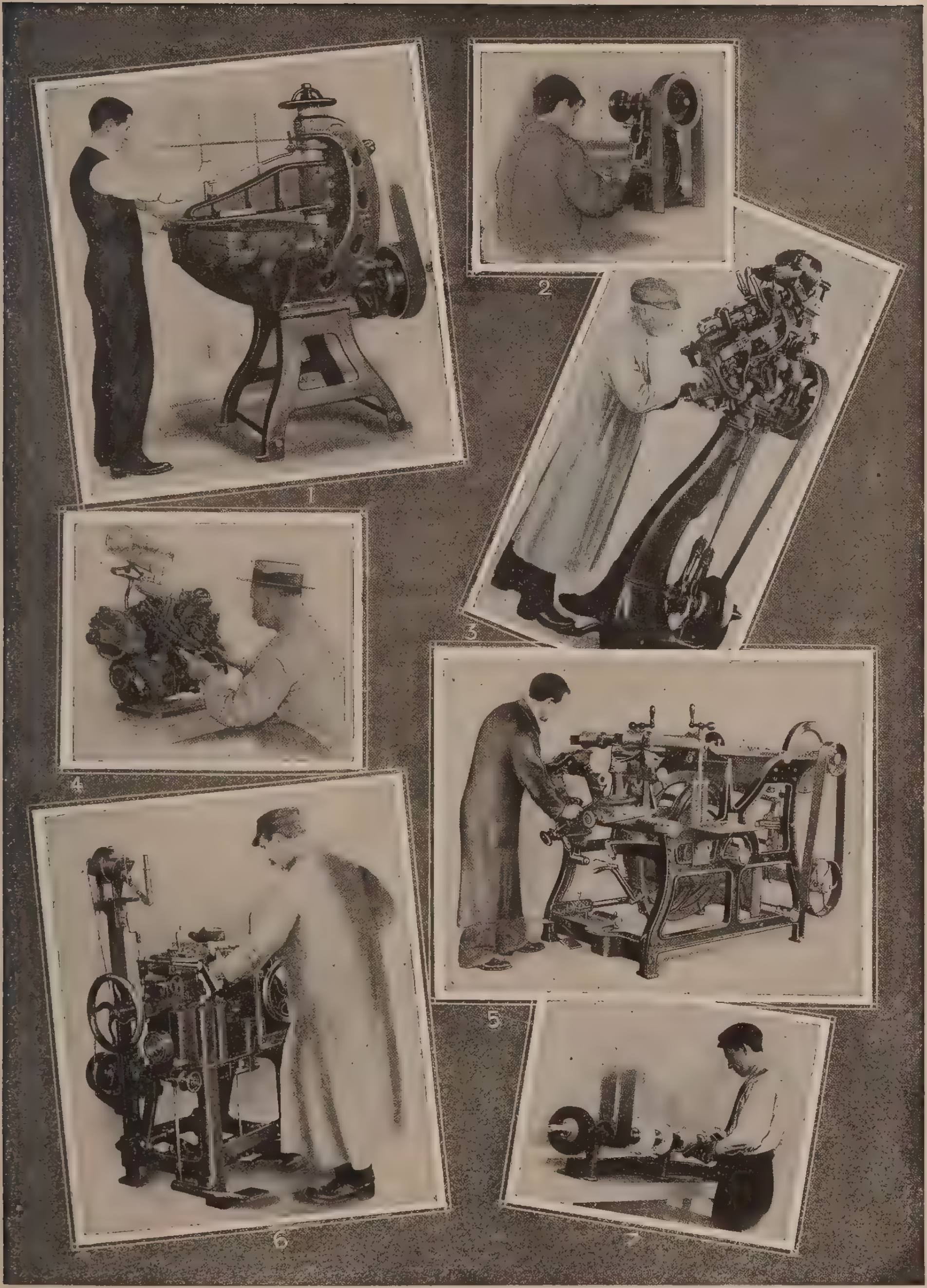
The leather is now ready for use, and the uppers for the shoes are cut out on a "clicking machine," which not only turns out the leather in the necessary shape but also marks the location for the tip and, if desired, the "foxings." The edges of the material which are to show when the shoe is done are beveled off by a "skiving" machine, while a different machine stamps out the perforated tips in any pattern wished. Upon a tag accompanying the leather is a schedule of the size, variety of material, kind of lining, stays, and style of the shoe, and this tag goes to the clicking machine, so that when the cut-out leather travels on to be sewed it has with it all linings and necessary parts for the finished article.

Stitchers then set about uniting these various parts of the upper, using wonderfully complex sewing machines, which do many different things at once. Holes for the eyelets are spaced exactly opposite each other, punched, and the eyelets put in by an eyeletting machine.

The best eyelets are of solid color on top and are clinched inside the shoe with metal; an eyelet made with a metal finish soon turns brassy and cannot be remedied unless replaced by one of the "fast color" variety. When all this has been done, the shoe-upper, with its tag, is sent on to the bottoming room, there to await the coming of the sole-leather parts which have, in the meantime, been made for it.



A MACHINE FOR COATING THE SURFACE OF A HEEL WITH HOT WAX, BLENDING IT IN BY MEANS OF A CLOTH-COVERED BRUSH, AND BRUSHING IT TO A POLISH BY REVOLVING BRUSHES



Courtesy United Shoe Machinery Co.

1. Ideal upper leather die-cutting machine, a great time saver. 2. Power tip press, or ornamental hole cutter. 3. Rex pulling-over machine, by which the shoe upper is prepared for lasting. 4. Duplex eyeletting machine, which eyelets both sides at once. 5. Goodyear automatic sole-leveling machine, which removes all unevenness in the shoe bottom. 6. Toe and heel lasting machine. 7. Climax finishing shaft: the various brushes give the shoes their high gloss and fine finish.

HOW THE SOLE IS PUT ON

These parts are the outsoles, insoles, counters, toe-boxes, and heels — many parts, you see, to keep track of and make to fit correctly. Sole leather is usually tanned with bark and is heavy and strong. The soles are first roughly cut from the big "sides" of leather by dieing-out machines, but afterward must be rounded off to conform to the required pattern for the sole. Then this outsole is passed through heavy rollers that compress the fibers of the material so that it will wear well. Next, the outsole goes to a splitting machine, which pares off the sole to a uniform thickness. While all this is being done the insole is receiving something of the same general treatment, and in addition a channeling machine cuts a slit along its edge, thereby forming a lip which, when turned up, guides the operator who is welting on the shoe. The heels are formed from many layers of leather cut in the proper size and shape, cemented together, and pressed down firmly by machinery. The counters for holding up the heel, and the toe-boxes, or stiffening, to be placed between the toe-cap and the vamp, are also prepared and sent on with the soles to the room where the shoe-upper is awaiting them.

If the shoe is a laced one, strong twine is passed through its eyelets so that it may be held in its natural position while it is being finished. Now the parts of the shoe are ready to be put together. The toe-box is placed in position to give form to the toe; the counter is put in to hold up the heel; and the upper is drawn over the last. To the bottom of this last the insole has already been tacked.

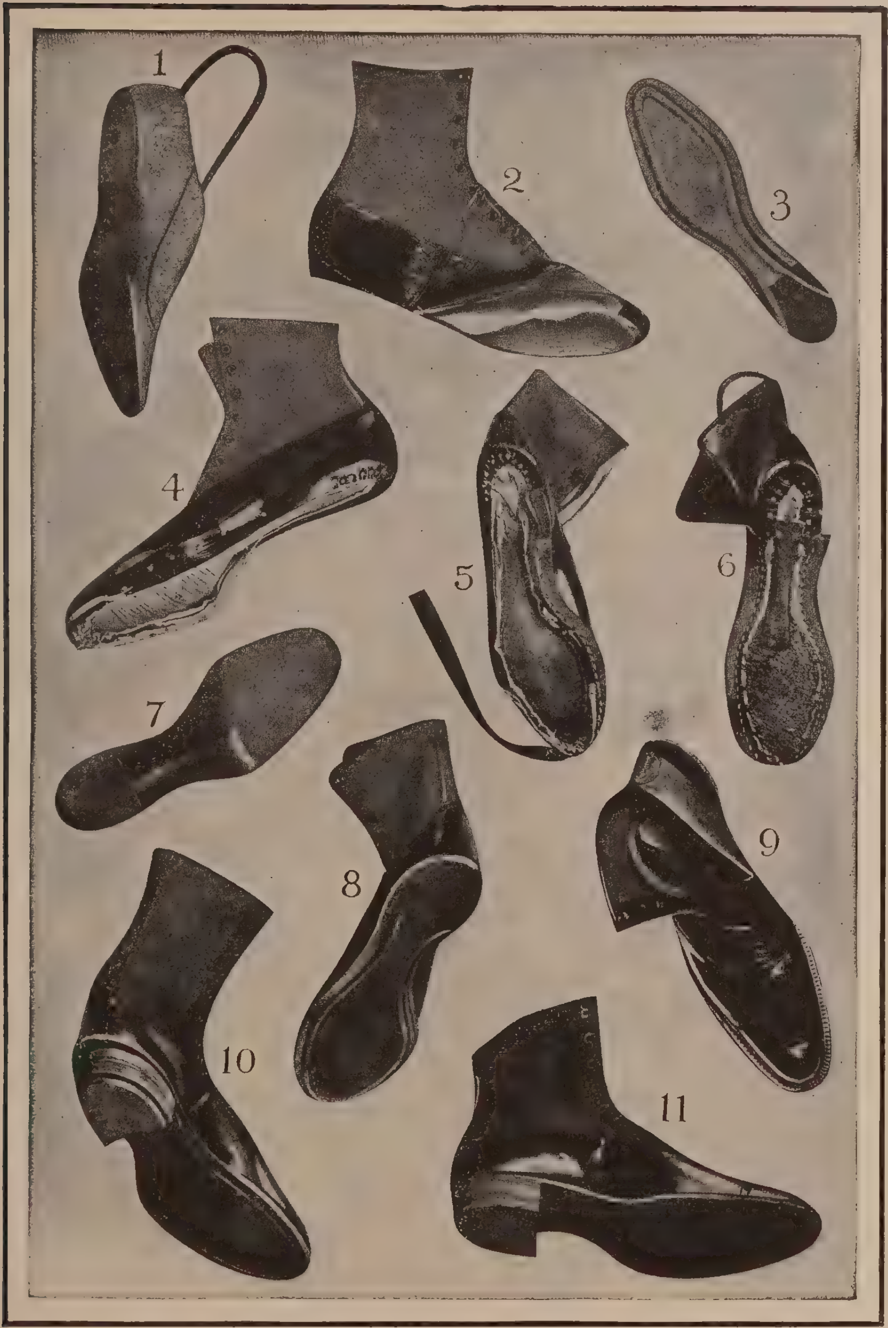
The last is a very important factor in shoemaking, since upon its shape depends the shape and size of the finished shoe. A workman puts the upper on the last and after seeing that the seam at the heel is in the right place presents it to a machine which drives two tacks which hold it securely in place at that point. He then hands it on to the operator at the pulling-over machine. This machine plays a vital part in the process, for it is the one that draws the forepart of the shoe upper down to the last and enables the operator to quickly adjust every seam to its correct position on the last, and the secondary motion of the machine drives five or seven tacks, as may be required, to hold it in place.

The lasting machine now draws the shoe upper and lining evenly and tightly around the edge of the last, simultaneously driving tacks to hold them in place. If it is a Goodyear welt shoe, these tacks in the forepart of the shoe are driven but part way in so that they may be afterwards removed. A little trimming machine then cuts away any surplus material.

The welt, which is a narrow strip of leather, is sewed around the edge beginning where the heel is placed on one side and ending at the same spot on the opposite side. The needle on this machine works on the arc of a circle and does not go inside the shoe but in the between substance of the insole and unites the insole and the shoe upper and lining through this means. A machine trims off the surplus part of the welt smoothly and accurately down to the stitches, all the tacks in the forepart of the shoe are withdrawn, and the welt is beaten out so that it stands out evenly from the edge of the shoe.

The shank piece, which gives permanent form to the curve of the sole, is tacked in place and a layer of ground cork and rubber cement is added to make up the difference in height occasioned by the addition of the welt. The surface of the welt and filler are then coated with rubber cement, as well as the flesh side of the outsole, and both are pressed securely together by a machine for that purpose. The welt and outsole are then rounded or trimmed so that they bear proper relation to the shape of the shoe and the welt is stitched to the outsole by a machine which makes a secure lockstitch. It is in this ingenious manner that shoes are made which are perfectly smooth inside.

The shoe is then placed on the jack of a heeling machine and all the nails are driven at one time. Then follows a long series of trimming, buffing, and polishing operations, varying with the quality of the shoe produced and the ideas of different manufacturers. In making some shoes, as high as 210 operations are required after the order is received in the factory, 174 of which may be performed by machine and 154 by different machines.



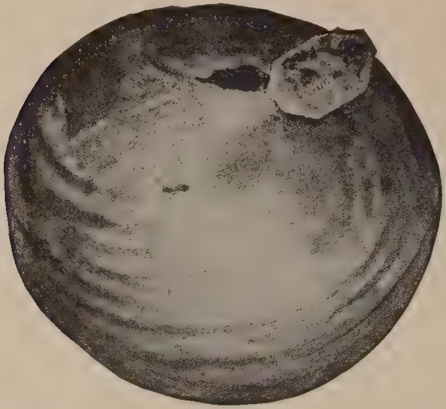
Courtesy United Shoe Machinery Co.

THE EVOLUTION OF A SHOE

1. A last. 2. An upper. 3. An insole. 4. Shoe lasted and ready to have welt sewed on. 5. Welt partially sewed on. 6. Welt entirely sewed on and shoe ready to have outsole laid. 7. An outsole. 8. Shoe with outsole laid and rounded. Channel lip turned up ready to be stitched. 9. Shoe with sole stitched on. 10. Shoe with heel in place. 11. Heel trimmed and shoe ready for finishing.

THE STORY OF RUBBER

THE romance of modern industry lies in the fact that it is so very modern. As we trace out the story of one great industry after another, the marvel is that from the point of view of the time covered the history of each is so short. Products which are taken for granted as comforts, conveniences, and apparent necessities of our present life, prove to date back only a brief thirty, fifty, seventy-five, or at the most one hundred years.

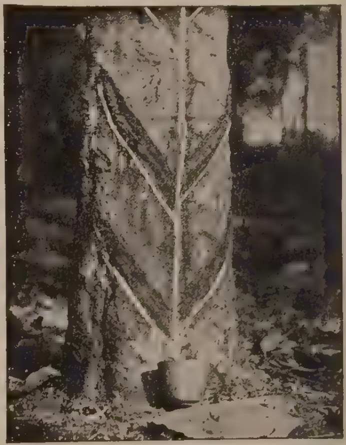


BALL OF RUBBER

Rubber is so familiar in the daily life of the American home that we are hardly conscious of its omnipresence. We protect ourselves in wet weather by rubber footgear, rubber garments, rubber hats; we water our gardens with rubber hose; we fit up our bathrooms and kitchens with convenient rubber articles; we play our games with baseballs, golf balls, tennis balls, made with rubber as a basis; we depend on rubber connections and rubber insulation of wires for the service rendered by our telephone, our electric light system, and our street-car system, while our firemen would be well-nigh helpless to protect our homes without rubber; and we are saved many a jolt and jar as we ride abroad by the rubber tires with which modern vehicles are shod. Each one of these great modern industries which we are studying is fascinating in giving us a picture, taken from its own particular angle, of the rapid progress of our world within the possible lifetime of a single man.

AS RUBBER WAS DISCOVERED

When Columbus landed in the West Indies and set his men to make clearings in the forest, he noticed that there oozed out of certain trees a milky fluid. Spaniards visiting the New World in the sixteenth century found the natives playing games with a ball made of a peculiar dark substance that formed from the milk of a tree. Two hundred and fifty years passed before much more attention was paid to this sticky substance which the French called "caoutchouc," or "weeping tree," from two Indian words, — *caa*, meaning "tree," and *o-chu*, the verb "to weep." By this name, borrowed into our own language, it might have gone for all the years to come if an enterprising Englishman had not discovered in 1770 that pieces of this substance would erase pencil marks from paper, and put it on sale for this purpose; whence the artists, with true Anglo-Saxon practicality, called the stuff "rubber" because it rubbed, adding sometimes to the name by terming it "India rubber," since it came from the West Indies. So it is from the present schoolboy and desk use that rubber originally got its English name, although this part of its work is now one of its smallest services to mankind.



Courtesy Hood Rubber Co.

METHOD OF TAPPING

Fortunately for the march of our civilization there are always in our midst inventive souls

A TAMBO, OR SHELTER, ON THE BANKS OF A RIVER IN THE AMAZON RUBBER DISTRICT

It is surrounded by an endless tropical forest and jungle. For thousands of square miles stretches a wilderness of beautiful trees and flowers, of strange birds and animals.

whose curiosity and love of research lead them to experiment patiently and persistently with any new substance that comes their way. Stories were brought home by sea captains and travelers that the natives of countries where the caoutchouc tree grew made ordinary garments partially waterproof by pouring over them this sticky tree-milk. Chemists began to experiment with this new substance. Two names should always be remembered in the early story of the industry,—Thomas Hancock, a business man in England, who devoted much time and money to the making and marketing of a variety of rubber articles, such as shoes, hose, carriage tires, and suspender cords; and Charles Mackintosh, who in 1823 in the city of Glasgow invented a process of spreading rubber between two pieces of cloth and holding them together under pressure until a waterproof cloth was produced. To this day we acknowledge our indebtedness to this inventor by calling waterproof coats "mackintoshes." The first coats were crude affairs, but they were useful as a protection against Scotch mists and English fogs. Similar garments were soon made in America, but here they did not work so well. The English climate had been fairly uniform. In the heat of our summers the coats became sticky and their rubber oozed away; in the cold of our winters they stiffened and became as hard as board. Dissatisfied purchasers threw them back on the luckless manufacturers with complaints of utter dissatisfaction, and the industry was on the point of coming to an inglorious end in the bankruptcy courts.

Then another inventor, Charles Goodyear, an American, steps into the scene, and for the next twenty-five years holds the center of the stage with his process for hardening and stabilizing the raw product. Rubber by itself was not commercially serviceable. It must be combined with something else or treated by some process to make it useful. Goodyear worked in his kitchen with saucepan and rolling pin, mixing this sticky dough with one substance and another, trying it at one heat and then another, until finally, when his money was exhausted and he was shabby and half starved in the struggle to maintain himself and still carry on his experiments, he hit on a combination of rubber and sulphur, brought together under certain conditions of heat, which accomplished the desired result. The problem was solved; rubber became a useful and workable commodity. The process thus discovered by an American was named by an Englishman "vulcanization," from the old Roman fire god "Vulcan," whose heat was necessary to secure the result. Today, as in the first days of the invention, every bit of rubber which we use is vulcanized.

THE RAW PRODUCT AT ITS SOURCE

In each industry we start with a raw product and wind up with one or many finished products. The industries which we have been describing thus far in this volume are comparatively simple in their dependence on a single raw product. Wheat is a plant product which must be garnered and put through certain refining processes before it is suitable for use as a food; the lumber, paper, and rope industries are concerned with the purifying and adapting of a vegetable product to desired uses; iron ore and fuel are brought together under certain conditions, and iron or steel result. The rubber industry is more complicated in needing several raw products; but at the basis there must always be the original milk of the rubber tree, or, in the case of synthetic or artificial rubber, its chemical substitute.

Raw rubber, caoutchouc as it is technically called, is a vegetable product of the tropics. To see the milk oozing from the rubber tree at the slash of a knife into its bark one must leave our temperate zone and travel either into the jungle regions where it grows wild, or into the tropical or semitropical countries where rubber plantations have been planted and tended, and its cultivation is an industry in itself. Many species of tropical trees are milk-producing, though only a very few have been found to be commercially profitable; while many plants not found in the tropics have the same qualities in their sap as do the rubber trees. Milkweed is one of these, and some attempts have been made to extract rubber from its thick white juice. These experiments, however, have not been successful. The white juice of the rubber tree is called "latex," and just as all the sap from the maple tree is not sugar so all the latex is not rubber. The globules of rubber rise on the sap as cream does on milk and must be separated from it. This separating may be done in several different ways. In mills it is done by artificial heat, or a combination of natural heat and chemicals; but in the hot countries natives do it by processes they have themselves invented.

When latex is to be collected, men start out into the forests or jungles carrying knives and a great many little clay or metal cups. They first make an oblique cut across the trunks of the rubber trees and then, having opened the veins where the latex flows, they fasten at the lower end of the gash one of the small cups by sticking it to the tree with a bit of clay. These cups are emptied into a pail each morning.

The latex, however, has so much water in it that if it were to remain in the pails it would soon ferment. So the natives dry and cure it. They first dip into the sap a piece of wood in the shape of a paddle. This paddle they hold in the smudge rising from a fire made of nuts which grow on a particular variety of palm tree. The paddle is waved about in the smoke until the rubber on it is thoroughly cured; then it is dipped again in the latex and thrust into the smoke once more. This process continues until a large ball of rubber about the size of a man's head is cured. This is then stripped off and is ready to be sold. The balls are called "biscuit rubber"; in some places the "biscuits" are smaller and of a different shape, and these are called "thimbles," "knuckles," or "nuts."

RUBBER IN COMBINATION

Interesting as it would be to follow rubber from its native jungle or plantation to our own shores, we are less concerned with this raw substance than with the results as they issue from our factories. All industries have certain similarities. The raw product as it comes from forest or plantation, from field or mine, must be cleansed of impurities. Plantation rubber is usually sufficiently clean so that its sheets need only be brushed; but "wild" rubber must be thoroughly washed and then most carefully

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INDIA RUBBER TREE

From such trees comes the milky fluid, the "latex," which is the basis for our rubber articles

dried under conditions which will not allow it to deteriorate. From this time on the business of mixing the rubber is a chemical process requiring extreme care and accuracy.

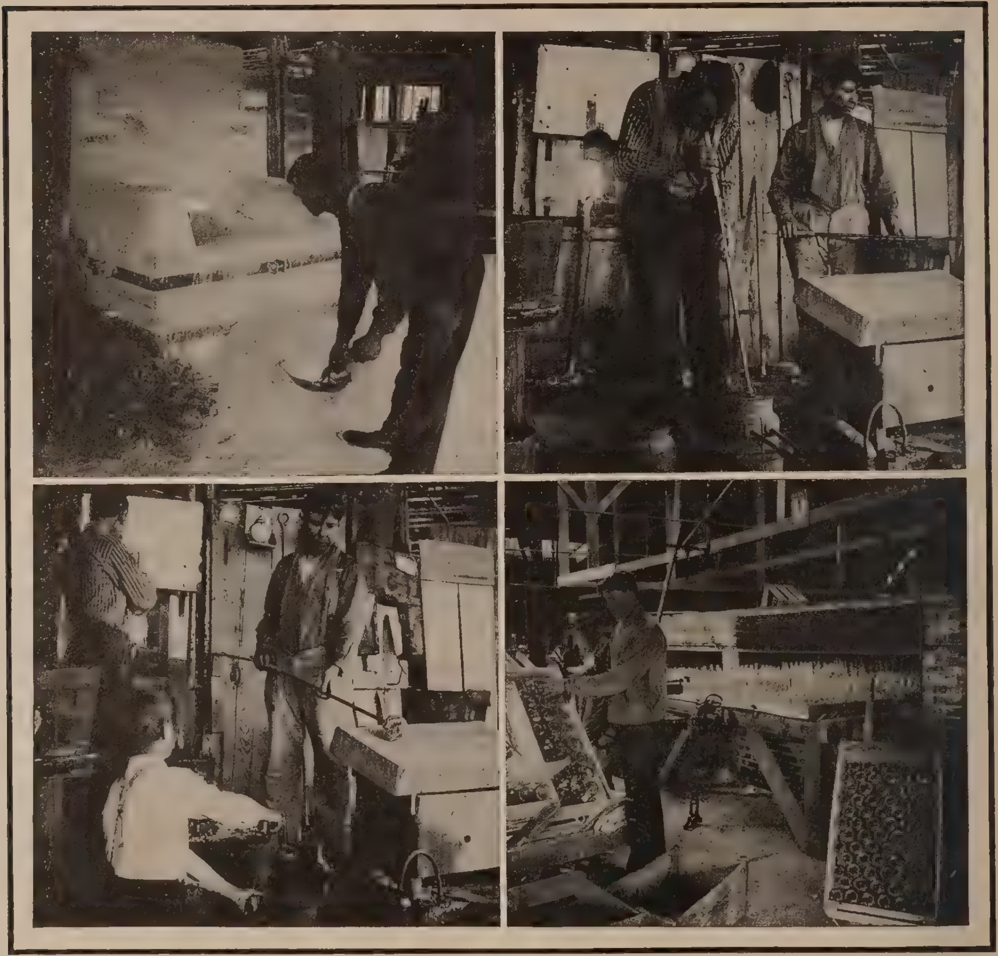
Pure rubber is soft and elastic. It becomes sticky when heated, and melts at a temperature of about 300° Fahrenheit. It does not dissolve in water. Indeed, in one sense, it does not dissolve in any of the substances with which it is combined; it takes these liquids, these solvents, into itself, and swells with them as a sponge swells with water. To get dry sulphur powder and pigments like gas black and zinc oxide and other ingredients of the chemist's formula into the original raw rubber is a matter of careful and skillful mixing under most exact conditions of temperature. Enough for us that the chemist does it, and that the various kinds of rubber come out suited for our uses, whether they be for the indispensable jar ring of the housewife who is preserving fruits or the automobile tire or the army balloon. One thing we should remember about the raw rubber which is the basis of all these combinations: it is plastic. It yields to pressure and then returns, if permitted, to its original shape. For this reason it can be molded with satisfactory results. For this reason it will take in all these other substances which we introduce into it to give it greater elasticity, durability, or hardness. In some factories as many as five hundred different substances, known as "pigments," are introduced into the various rubber mixtures desired for one purpose or another. As we know from experience with the rubber bands which hold together packages of papers in our desks, or with the cord of a boy's sling shot, rubber stretches to a greater degree than any other substance. Herein lies the secret of its great usefulness in manufacture. As it stretches it stores energy. Stretch wood or steel a very small proportion of their length in any given piece, and they give way or break. But rubber can not only be stretched an amazing amount; it will also hold in itself the desire to return to its natural or original shape or length. That desire to return may be measured as the energy stored in the rubber. In returning to its original length the rubber will release that energy, which will drive the stone out of the sling shot or do any other piece of work we set it.

THE NEXT STEP

Even a rubber mixture is not the finished product. If we knew nothing of the previous steps we might almost call the carefully prepared rubber mixture the raw product, for such it is to the multitude of industries in which it is used. As the native of the West Indian jungle spread the sticky tree-milk on his clothes, so the modern manufacturer makes his molds or designs for rubber garments, rubber shoes, rubber hose, or rubber tires out of some fabric like cotton and coats them or lines them or in some way treats them with rubber. Or, if the product is to be of solid rubber, he must have molds in which to shape it. The recent progress of the rubber industry has depended in large measure on the vast number of machines designed to carry on the later processes of the transformation of rubber into every conceivable article, from gas masks and rubber gloves to the huge conveyor belts of the modern mill. First the raw rubber, then the rubber mixture, then the mold or design, then the finished product: such is the story of every rubber article.

GUTTA-PERCHA AND GUM

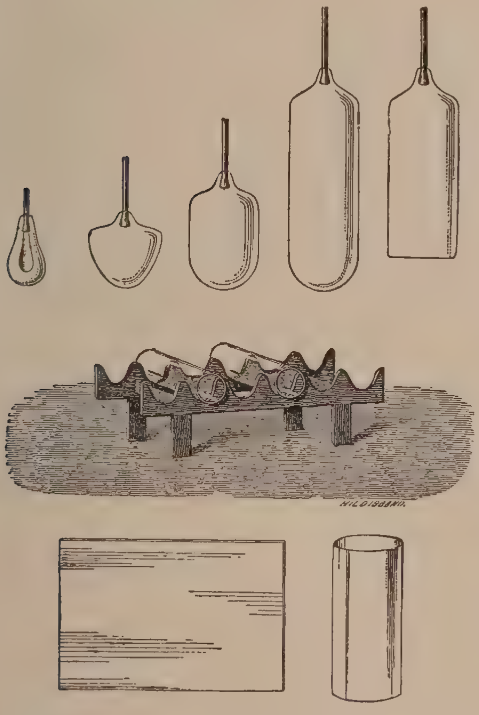
Rubber has also its companions, though not its rivals, in other substances from the milk of other tropical trees. One of these is gutta-percha, which resembles rubber in being waterproof, and also in resisting the passage of electricity. As a good insulator it is used in factory work and in submarine cables. Balata, a somewhat similar substance, is used in belting and in covering golf balls; while chicle, more plastic than caoutchouc and more elastic than gutta-percha, is the base of our American chewing gum.



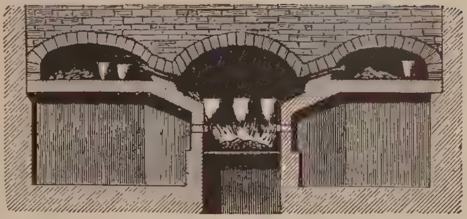
LEFT: SHOVELING THE MIXED "BATCH" INTO THE FURNACE, AND DIPPING AND SHAPING MOLTEN GLASS. RIGHT: BLOWING THE BOTTLE INTO REQUIRED SHAPE IN A MOLD, AND PACKING FINISHED BOTTLES

GLASS-MAKING

THE date and origin of the first glass-making are unknown. On the tombs of Beni-Hassan at Thebes, dating back 2000 years B. C., there are pictures of Theban glass-makers at work; a glass bead bearing the name of Queen Hatasou, who lived about 1500 B. C., and was the wife of Thothmes III, was also discovered at Thebes. When Cæsar Augustus subdued Egypt in 26 B. C. he ordered that glass should form part of the tribute of the conquered people. Accordingly quantities of glass products were sent to Rome, where the fastidious Romans eagerly bought them up and eventually made glassware one of the large export trades of the Egyptians. During the reign of Tiberius (14 A. D.) the industry was taken up in Rome itself, and soon the Romans outrivaled their predecessors in the shape, coloring, and cutting of glass objects. In fact, the many glass household articles found in Roman tombs prove that glass was in very common use in those days. In ancient provinces of France glass relics have also been discovered, showing that at an early date the Gauls were rivals of the Romans in glass-making. Primitive glass work was found in Spain as well.

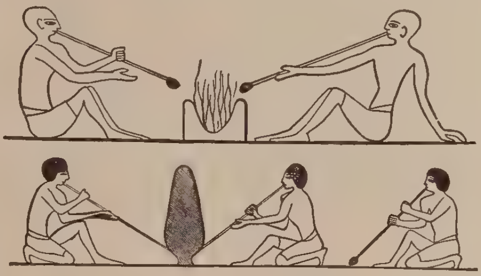


BLOWING OF SHEET GLASS, FIRST INTO A PEAR-SHAPED MASS, THEN A CYLINDER, WHICH IS OPENED INTO A SHEET

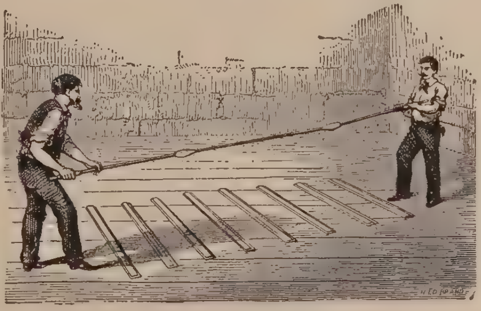


GLASS FURNACE

Then the barbarian hordes swept down upon Rome and the adjacent countries, and all these industries perished and were not again revived until Constantine the Great moved the Byzantine capital to Constantinople and drew there artists of every variety. Then gradually the Venetians, by nature great travelers and traders, came to the front as glass-making artists. Probably at St. Sophia they saw the windows of colored glass, a product quite new to them, and became interested in copying it. They had long made pictures in mosaic, using bits of vari-colored glass. Now on their tiny island of Murano they began experiments which resulted in the beautiful old windows of St. Mark's, as well as in numerous marvels of spun and blown material. Venetian glass, still made at the old Murano works, is world-famous. The art was for centuries kept secret, and no glass-maker of the Republic was allowed to take up residence out of Venice on pain of death. These craftsmen were regarded with great respect, and were allowed to marry with the nobility. The most wonderful work of the Venetians was their imitation pearls of blown glass, their colored glass, and their delicate



THEBAN GLASS BLOWERS



DRAWING OUT GLASS TUBE

MODELING CLAY POTS FOR MOLTEN GLASS

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DRAWING A POT OF HOT LIQUID FROM FURNACE

filigree or spun glass. So popular did spun glass become that we read of a foreign prince who made a great sensation by appearing in Paris with curls of finest black spun glass.

DEVELOPMENT IN GERMANY, BOHEMIA, AND FRANCE

Germany, meanwhile, began to produce glass of a very different type—great vases, tankards, and drinking goblets decorated with coats-of-arms in enamel. The most ancient of these vases, having upon it the crest of the Elector Palatine, bears the date 1553, and may be seen at the Kunstkammer, Berlin. In Nuremberg, Albrecht Dürer and other renowned German artists were gaining success at stained glass-making; to Kunkel, a Saxon chemist, Germany is indebted for the ruby-red variety.

Bohemia, in the seventeenth century, surprised the world with an engraved glass done either by lathe or diamond and worked in gold or colors. Belgium and England were all this time turning their attention to fashioning crystals and cut glass. Very beautiful glass was also made in France from the sixteenth to the seventeenth centuries, and in the various museums drinking glasses and vases manufactured for the French kings may be seen. About this time a colony of Venetians settled near Limoges; and the people, already clever at enamel-work, began experimenting with stained glass. After many difficulties they mastered the art, and their work is still found in many of the old French cathedrals. At first this glass was faint in color and followed the conventional designs of the orientals, whose Mohammedan religion forbade them to make human likenesses; later, the tones of this early glass deepened, and the Bible pictures, or scenes from the lives of the saints, took the place of the floral traceries. These tales in glass served two purposes: they beautified the churches, and they acted as story books to the masses, who were unable to read.

At present glass-making has widened its scope. Not only do we purchase numberless glass objects for decorative purposes, but we use for

THE POLISHING ROOM

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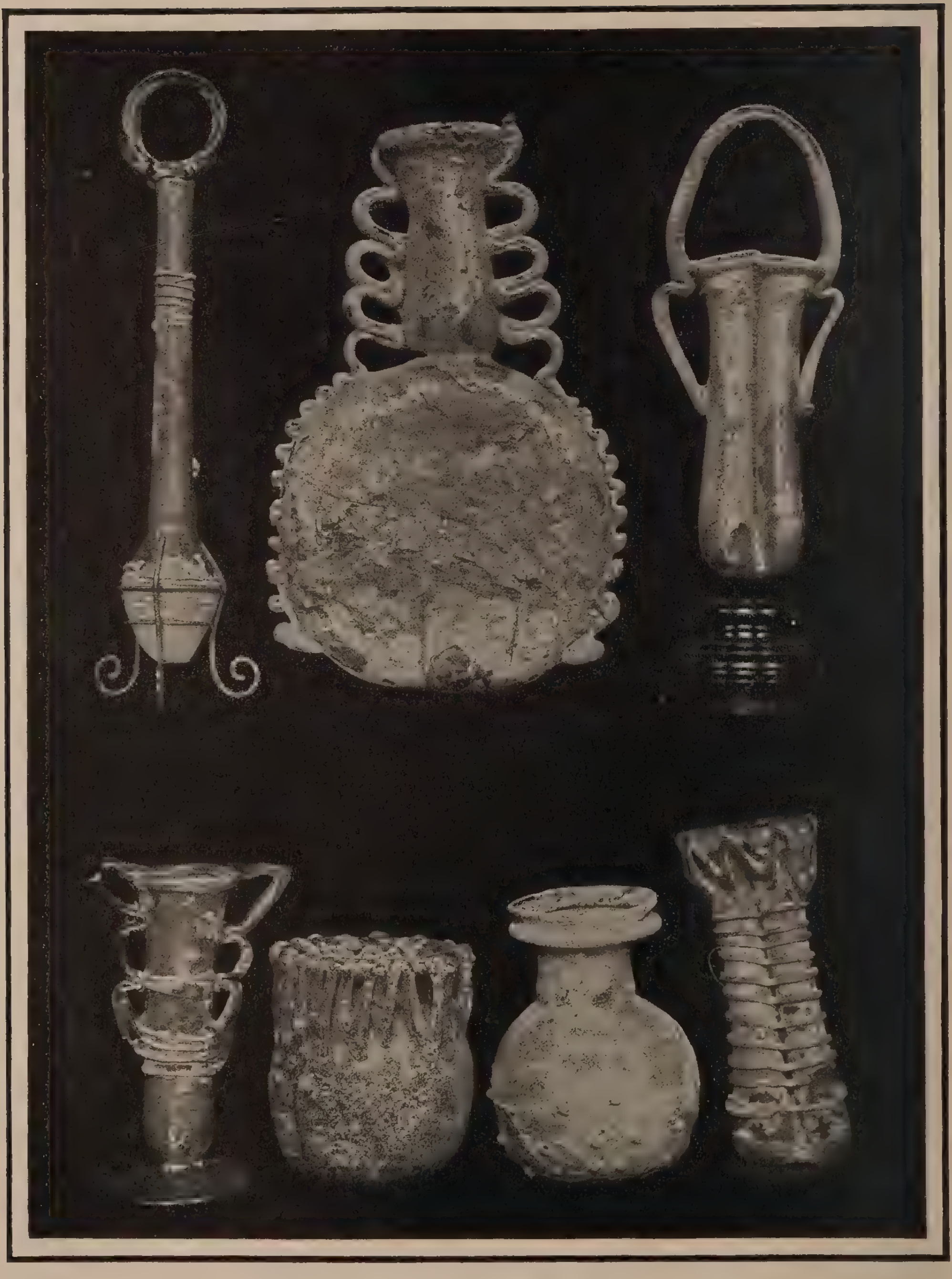
CASTING AND ROLLING SHEETS OF PLATE GLASS

household conveniences more glass than any other nation in the world. American artists like La Farge and Tiffany have designed and executed exquisite stained glass, and Tiffany is also turning out art glass of striking beauty. In addition to its esthetic value glass, as a non-conductor of electricity, has taken an important place in industrial and scientific fields. Thermometers, test-tubes, lenses, spectroscopes, microscopes, and electric-light bulbs are all dependent on glass for their being. The looking-glass, in early days a pool of still water, and later a sheet of polished metal, is now made from thick plate glass; and no longer must man resort to oiled skins or paper to keep out the cold or let the light into his dwelling. Wire-glass, used for skylights, etc., was invented by Frank Schuman, an American, and has proved to be most useful where large, heavy panes of glass are employed; not only does the wire incorporated in the glass help to support the weight of the material, but it also catches the pieces and prevents injury should the glass break and start to fall.

HOW GLASS IS MADE

Glass is made from a mixture of silica, a form of sand or quartz, with some other material. To make window-glass, soda and lime are blended with the silica; for bottles, a small amount of oxide of iron may also be present; for crystal, potash and oxide of lead. For enamels, oxide of tin is mixed with the soda, lime, and silica. Silica may be found almost everywhere. Rock crystal, sandstone, flint—all contain silica. The art in the glass-maker's trade lies in knowing just what proportion of these ingredients to put in. When these materials have been properly measured out they are melted together until they are reduced to the consistency of thick molasses. The good qualities of window and plate glass are made by pouring this liquid upon a flat surface and allowing it to cool, after which it is ground smooth and polished; cheap glass, on the contrary, is first blown into large, hollow cylinders and then cut into a flat piece, smoothed out, and polished. Glass blowers, because of their con-



GRÆCO-ROMAN GLASS VASES

Reproduced from specimens at the Museum of Fine Arts, Boston.

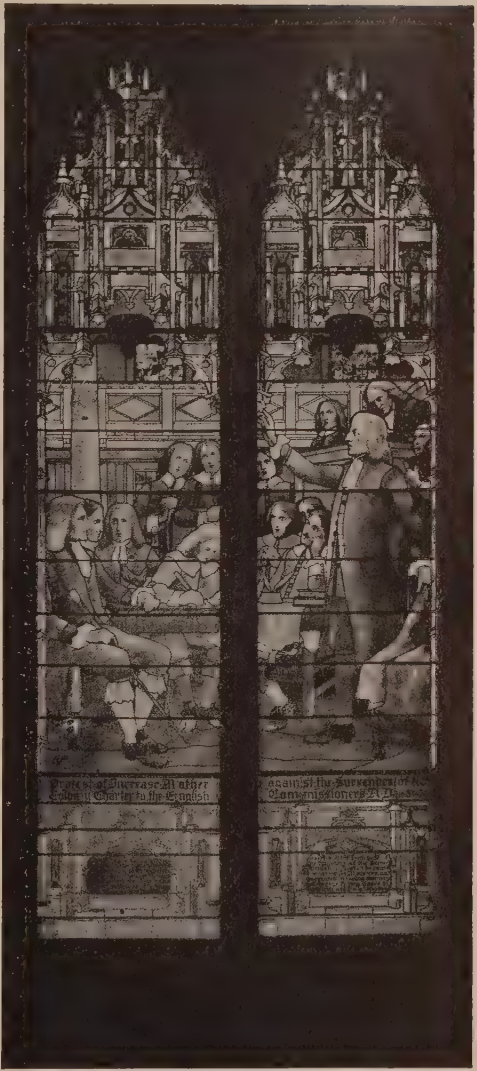
tact with the hot furnaces, are obliged to wear masks, or shields, to protect their faces, and coarse gloves on their hands. The gatherers collect a mass of the melted, gummy glass on the ends of their blowpipes, and after turning it in a mold so that it assumes workable shape, they pass it on to the glass blowers. Sometimes this massive globule of molten material will weigh from twenty to forty pounds. You can readily see, therefore, that the glass blower must be strong as well as skillful. As he twists and turns the great bubble at the end of his pipe he continually blows into it draughts of air. When the vast cylinder is made it is brought back to the furnace, where one end is softened and penetrated with a sharp-pointed object; the opening thus formed is then made larger; the mass is afterward detached from the blower's pipe, and cut down the side so that the glass may be spread out flat. If a shaped glass is desired, the material is molded or pressed into the required form.

HOW THE COOLING IS GRADED

The annealing, or cooling, has much to do with the quality of glass. If cooled quickly in the air, it becomes delicate and brittle; if cooled gradually, it is much stronger. Hence ovens of slowly diminishing temperature have been invented where the glass may travel from one oven to another and become cool by almost imperceptible changes. Sometimes this process of graded cooling takes many hours. Until

TWENTY-FOUR-INCH CUT GLASS PUNCH BOWL

It is called the "Lewis and Clark Masterpiece," as it was made especially for the Portland Exposition in 1905, and took first prize as the largest individual piece. Its value is $3,000.


Protest of Increase Mather against the Surrender of the
Colony Charter to the English Commissioners A.D.

STAINED GLASS MEMORIAL WINDOWS IN THE SECOND CHURCH, BOSTON

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CHINA DECORATORS AT WORK, NEAR KYOTO, JAPAN

the invention of these cooling tunnels, weeks were often consumed in annealing glass.

CUT GLASS

Cut glass is made upon grindstones moistened by wet sand, or is cut by revolving emery wheels. After cutting it is polished with putty powder, jeweler's rouge, and chamois-skin. Pressed glass, made so extensively in America, is much like cut glass but lacks the sharp edges and prismatic coloring. It is, however, much cheaper and therefore has a wide sale. Stained glass may be colored throughout or simply tinted upon the surface. The coloring matter is blended with the mixture of sand, lime, and soda, but allowance must be made for the changing of tone in the firing.

HOW CHINA IS MADE

WHEN did man first begin to make dishes? To trace the origin of pottery and china we must travel back over centuries of history, and even then the date will elude us. Most races of the world soon discovered that they needed some sort of dish or bowl. Perhaps it was seeing a footprint harden in the sun-baked soil that first set them thinking they might fashion dishes of clay and dry them in the sun. But until man acquired the art of glazing his pottery so that moisture could not penetrate it, and of baking it in the fire, it was not really of much practical value.

The baking or firing of pottery was probably a chance discovery. Some bit of primitive clay-work may have fallen into the blaze, and instead of being burned came out hard and strong. One fact is certain, that until man learned to make fire and use it he could have made none of that ancient glazed earthenware, the relics of which can now be seen in many of our museums.

The Chinese and Japanese were skilled in glazing pottery fully three hundred years before the secret was known to European races. The Egyptians put a crude glaze on some of their earthenware, and so did the Greeks and Romans, but none of them equaled the perfected workmanship of the Asiatics. The Saracens and Arabs also discovered a method for enameling pottery with melted tin, and when the Crusaders returned from their pilgrimage to the Holy Land they brought back this art to certain parts of Europe. The people of Limoges, France, for a long time did beautiful enamel work; then came the turmoil of war, and the art was lost and never re-discovered. While this experimenting was going on, the Italians were making and decorating a sort of earthenware called Majolica, which, when baked, came out with a

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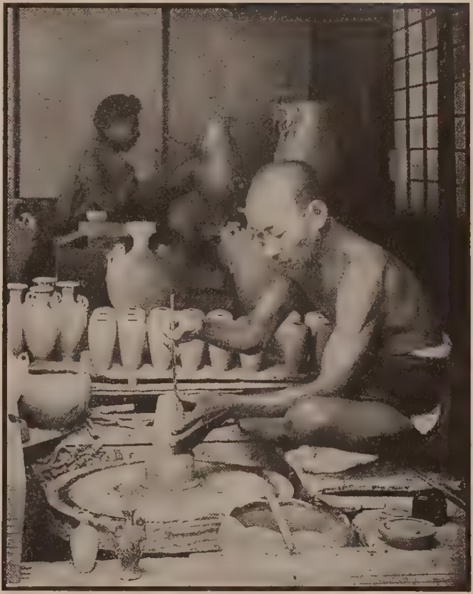
PREPARING CLAY AT PORCELAIN WORKS



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JAPANESE POTTER AND HIS WHEEL

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REMOVING POTTERY FROM THE KILN

glaze formed by the blending of its colors with lead. Later they too learned the Saracen art of glazing with tin.

If all these nations had shared the results of their experiments, we might have had china on our tables centuries before we did. But every country feared every other. Hence guilds, or unions, were formed to guard the secrets of every trade. As a result, every nation was eager to steal the processes of every other. It was a period of scheming and sacking, of treachery and violence. No methods were intrusted to writing lest they be stolen. The men working at various trades carried the secrets of their craft in their minds. It therefore came to be part of the policy of warring nations to capture and torture artisans in the hope of wringing the story of their trades from them. If this failed, the men could at least be killed, so that the art would die with them. What wonder that it took so long for discoveries to spread through Christendom! Each country had to work out for itself problems which some other might have answered for it. Palissy, the French Huguenot, starved himself and burned all his furniture as fuel during his sixteen years' struggle to discover how to obtain the enamel glaze he had seen on a Saracen cup. His story is a fascinating one.

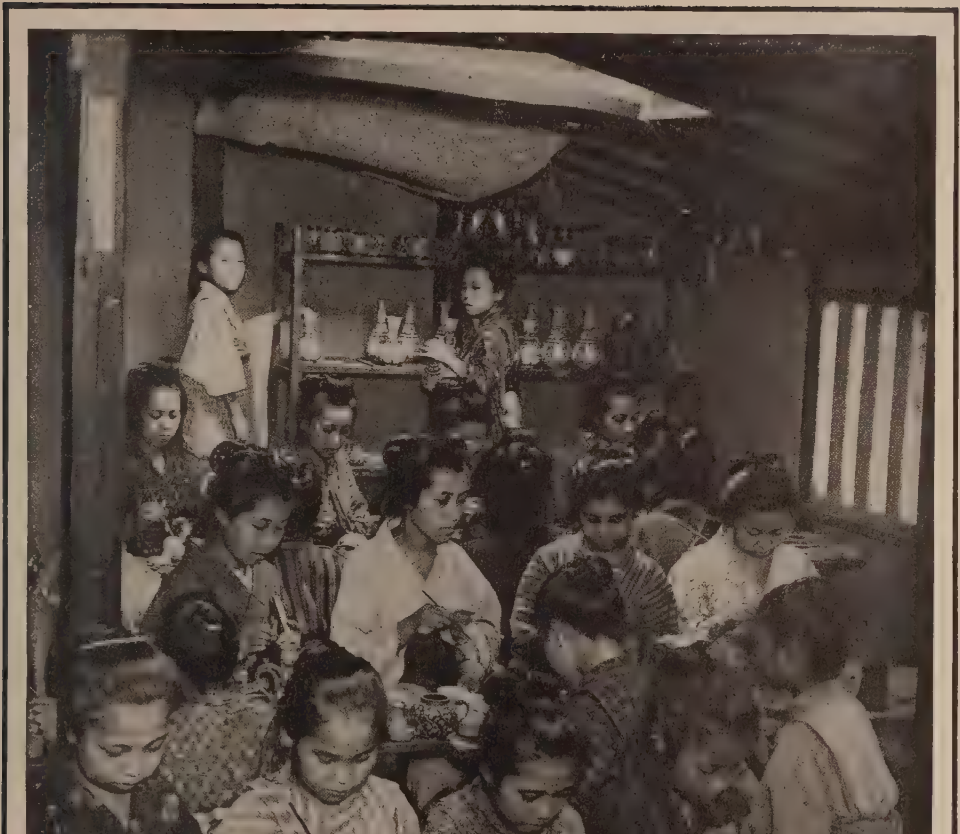
GIRLS PAINTING PLATES

In Germany, also, the people were wrestling with the puzzle of glazing pottery. They were making a clumsy sort of grayish earthenware with figures of blue, brown, and white for decoration; after sprinkling this ware with common salt and baking it, it came out with a rough glaze caused by the blending of the salt vapor with the clay.

AN ARTIST MODELING A FIGURE

HOW EUROPEANS GOT ON WITHOUT DISHES

All this time people had no such thing as china dishes. The poorer classes ate from tables with thick wooden tops, in the center of which was hollowed a trough for the food; those more well-to-do had wooden bowls and cups, and used



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DECORATING CHEAP POTTERY FOR FOREIGN MARKETS, KYOTO, JAPAN flagons of horn or leather; the rich had their bowls fashioned from pewter or brass. Life was very simple in those days. There was little variety in the food, and therefore few dishes were required. Tea, coffee, and cocoa were unknown, so there was no call for cups and saucers; nor were there soups, vegetables, or desserts. Each person ate with his fingers from the big trencher in the middle of the table, or from his own bowl. Since a guest more often than not ate out of the same dish with his host, and since all armor was laid aside during the meal, you can readily see that it was a mark of great trust and friendship to be asked to eat with anyone. Then the thirst for travel and trade developed. Nations began to send ships to other parts of the world. English and Dutch merchant vessels sailed to China and Japan and brought back a myriad of products hitherto unknown—such as tea, coffee, strange fruits and vegetables, silks, and porcelain.

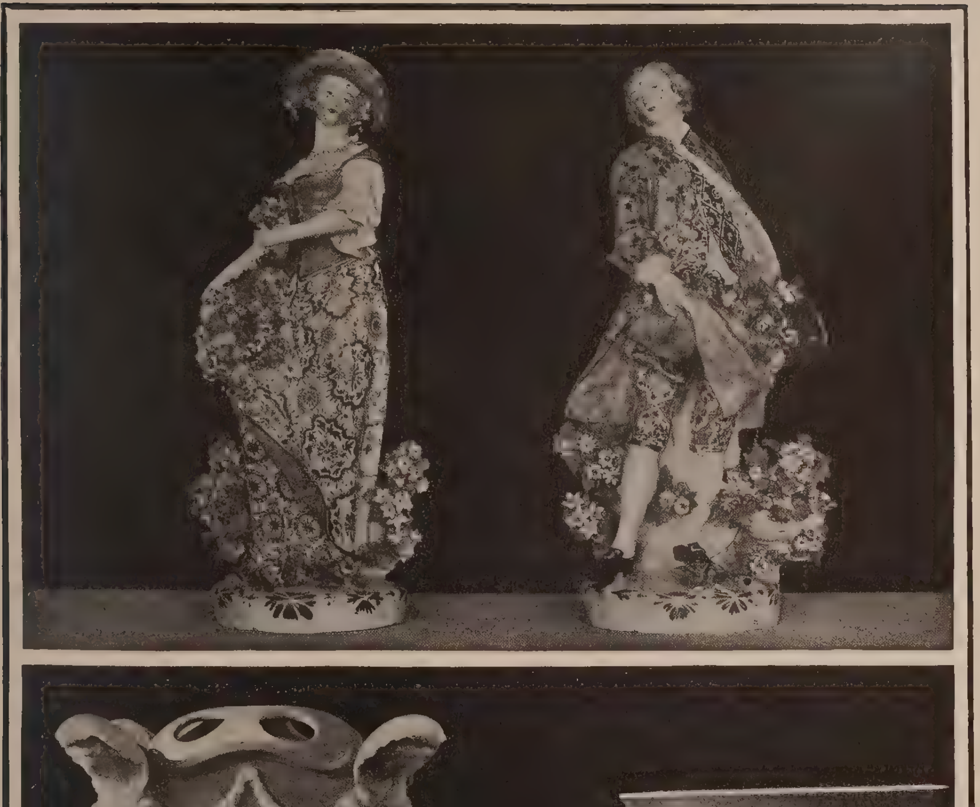
What a sensation all these new things made in the western world! With this increased variety of foods and drinks more dishes were needed, and people eagerly bought up the dainty blue and white china sent from the Orient. The thin teacups made without saucers by the Chinese and Japanese, however, were found to be impracticable in England, where oak or mahogany, instead of teakwood tables, were used; the heat struck through the delicate ware, marring the English woods so badly that saucers were necessary. Then, too, fruits and vegetables could not be mixed in bowls with meat. There must be plates. So Dutch workmen, taking pattern from the Chinese ware, set about making a blue and white china which they called Delft, and which had a hard, shining glaze upon its surface. How they made it they would not tell. As all this china was fashioned from oriental designs, it was without handles; it was many years later before teacups with handles were invented. Not to be outdone, England took up china-making too, but got no results beyond crude, salt-glazed wares such as Germany was making. How did the Chinese make that pure white porcelain of egg-shell delicacy? Everybody wondered. And what was the key to that marvelous smooth glaze?

HOW KAOLIN WAS DISCOVERED

From the seventh to the tenth century the Chinese had not only perfected the art of china-making but had guarded well their method. They now looked on with sealed lips and viewed the struggles of their neighbors. Foreigners were not permitted to come into China, hence there was no way to find out the secret. At last there was someone (as there always is) who needs must tell the story. A Chinese teacher traveling in Europe glibly explained that the beautiful white porcelain of the Chinese was made from nothing more mysterious than a fine white clay called "kaolin." It looked, he said, like ground wheat. This was the hint for which European chemists had been waiting. They began to hunt in the soil for a white clay, like flour.

In 1701, the King of Poland, who had become interested in the search for kaolin, set a chemist by the name of Böttger to looking for it. Böttger had already had some success with making earthenware, so the art was not entirely unknown to him. He was, moreover, something of a scholar — a fussy little man, with florid face and powdered wig; surely a strange sort of person to be sent hunting kaolin! What is more remarkable, he proved to be exactly the right person to go on the quest, as you will see.

One day, when his servant brought home his freshly powdered wig, Böttger complained that it felt unusually heavy, and so much fault did he find that at last the terrified servant confessed that he had sprinkled it with a new kind of powder. The powder was brought and Böttger examined it. He found that when mixed with water it made a clay not unlike that from which the Chinese porcelain was fashioned. Some time later at Aue, near Meissen Castle, a large supply of genuine kaolin was discovered, and the King of Poland, then one of the Electors of Saxony, founded pottery works there. This was the beginning of the world-famous Dresden china. But the king was quite as secretive about his china-making as was everybody else. His workmen were held captive in the castle, and all the clay stored for use was packed in barrels by deaf and dumb servants. At first the ware was made



TOP: ROW. THE FLOWER VENDERS. BOTTOM: WEDGWOOD. JASPER VASES only in blue and white, but gradually it came to be decorated with the many-hued flowers which we now see upon it.

In France the discovery of kaolin was also accidental. In 1768 the wife of a doctor by the name of Darnet, who lived not far from Limoges, was pulling weeds in her garden when she chanced to pull up one with quantities of fine white soil clinging to its roots. Thinking this white powder might be useful for making soap, she took it home and showed it to her husband. He was so curious about it that he took it to a chemist, who in turn carried it to the head chemist at the Royal Porcelain Works. Instantly it was pronounced to be kaolin, and in December, 1769, a number of pieces of porcelain made from the new clay were presented to the king. Thus began the making of china at Limoges.

THE FAMOUS SEVRES, DOULTON, AND WEDGWOOD WARE

In recent years an American named Haviland has invested a fortune in the pottery works at Limoges, and we now have in our country quantities of beautiful dinner sets of French manufacture which have taken the place of our early American stone china with its historic pictures, as well as our wares of later make. Thus far we are still unable to turn out china as fine as that of foreign manufacture. We must thank France, too, for that rare and delicate Sevres china, not made since 1804, and now so valuable.

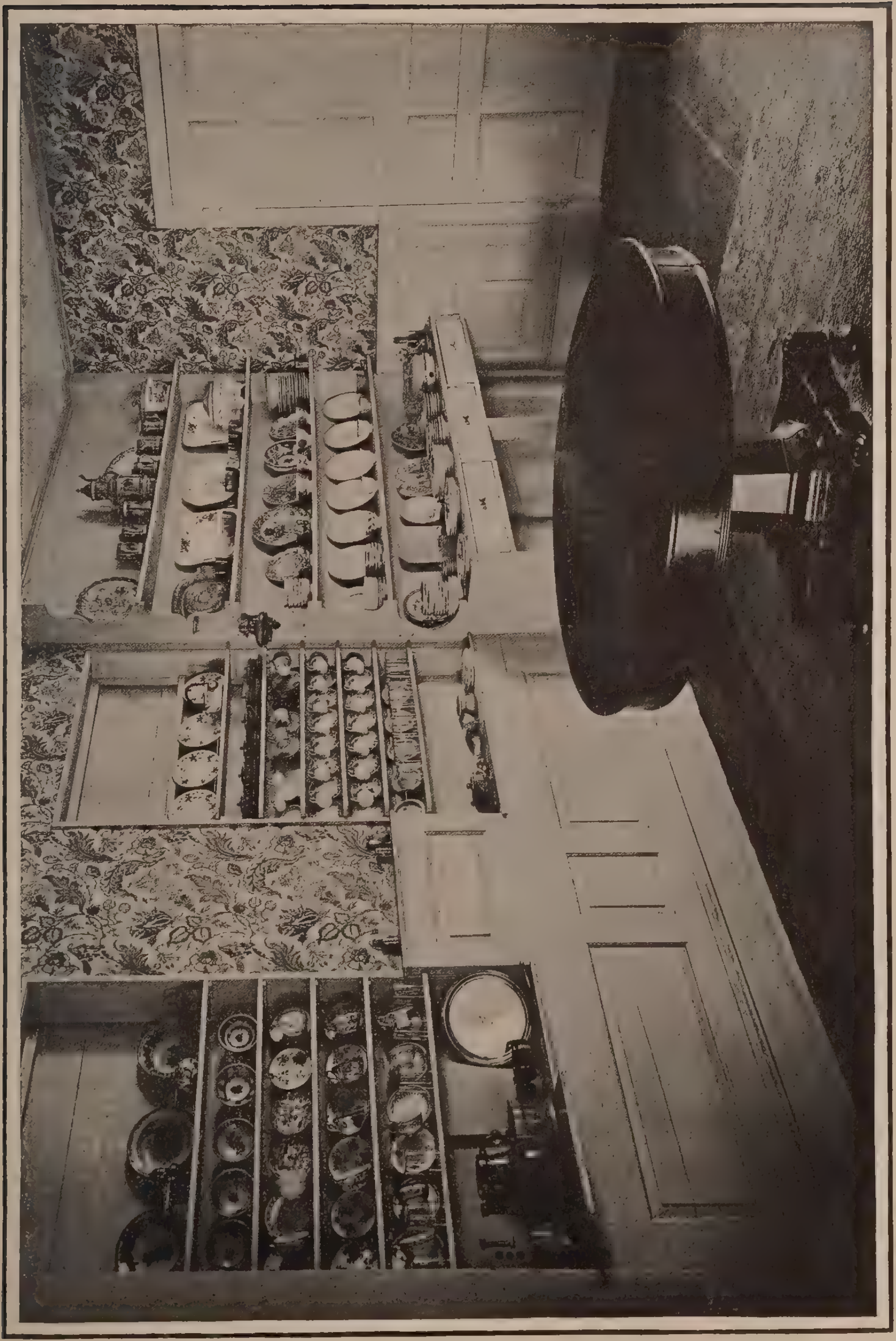
Many other celebrated china-makers have come down to us through history: Henry Doulton, renowned not only for the beautiful ware bearing his name, but also for his discovery of glazing drain-pipes which revolutionized sanitation; Wedgwood, the English potter, who first fashioned that unique china adorned with classic figures standing out with cameo-like delicacy against a background of dull green, blue, brown, yellow, or violet. Royal Worcester, Crown Derby, Copenhagen, Cantagali—almost all the great nations have furnished their own distinctively decorated wares. Those who have made a study of china can readily tell the history of the rarer pieces from the mark upon the back.

HOW CHINA IS MADE

The making of china is dependent upon two factors, the body and the glaze. The body must be made of carefully selected clay from which all impurities have been removed. This clay is a blend of kaolin (china clay) and blue (or ball) clay. The finer the grade of china the more kaolin is put in. Kaolin makes a thin clay, resulting in a very delicate china. Ball clay is more plastic and therefore stronger and less sensitive to changes of temperature. These clays are cleansed by mixing them with water; as they are lighter than any impurities blended with them, the clay rises to the surface of the water and may easily be drained off. There must also be put with this clay a certain proportion of glass-forming material—a finely crushed granite containing partially decomposed felspar. This agent is put into the glaze as well. Then we must have a specific amount of oxide of silicon or flint, which serves to prevent the contraction of the material and lends whiteness to it. To these ingredients is added oxide of cobalt, a deep blue mineral, not affected by heat. Like the felspar and flint, this cobalt must be finely powdered and sifted through gauze or closely meshed wire; otherwise the china will be specked with blue, as is so much of the very cheap ware.

After these materials have been mixed together and pressed through fine cloth, powerful magnets are applied to extract every particle of iron or other metal, as the presence of any mineral matter would be apparent after firing. The clay is then thoroughly kneaded by machinery and turned over to the potter, to be shaped by hand on the potter's wheel, turned on a turning-lathe, or molded by machinery.

Thrown ware, or that fashioned on the potter's wheel, is of more choice design and less liable to be duplicated than other china, since each piece is given individual attention. Both thrown and turned ware are also stronger, better made, and hence more expensive than machine-made wares. Since, however, we now demand hundreds of pieces of a kind, it is impossible to make it all by this slower and more costly method, and much of it must of necessity be made by machinery.



A GOOD COLLECTION OF OLD CHINA

The decoration of fine china is frequently done by hand; patterns on the cheaper grades of ware are stenciled. The glaze of the china is put on over the outside, much as paint is put on a house. After firing it fuses with the material and becomes a part of it.

GENTLEMAN-AT-ARMS

Figure-piece of Crown Derby, in the Museum of Fine Arts, Boston.

GEMS

THE custom of wearing gems originated centuries ago among the Egyptians, Greeks, and Romans. These people, however, did not wear such stones because of their beauty or their value, but because they believed that in them lay some charm against misfortune. Certain stones were considered lucky, others unlucky; some brought health and prosperity to the wearer, some were supposed to turn dull and lifeless in the presence of an enemy. The diamond was believed to ward off lightning; the opal to be unlucky; the amethyst to drive away evil spirits. Not all these superstitions have been routed even now, for there are still so many persons who hesitate to wear the opal that not nearly as many of these beautiful stones are sold as there probably would be if this stigma did not attach to them.

To those of us who have not studied the qualities of the various jewels it seems as if it must be very hard to detect real gems from imitations, and we have perhaps wondered how it is that those who handle them are so sure of their value. Why is not any flashing white stone a diamond? What is it that makes one sparkling brilliant worth a fortune, and another worth nothing at all?

HOW GEMS ARE TESTED

The person whose eye has been trained to the observation of jewels will almost instantly detect the true from the false; but if he cannot do this by sight alone there are several infallible tests to help him. It is not the color that decides him, for sapphires are often yellow or pink instead of blue, and there are green garnets and yellow diamonds. No, the expert cannot judge the stone by the color. He judges it by its formation. All gems are crystals which conform to certain laws of structure. The study of crystallography tells just how each of these crystals is made up. To this knowledge the expert adds his knowledge of minerals — which stones are hard, and which soft. The diamond is the hardest stone we have; next to it comes the sapphire, then the ruby, and so on down the scale of twenty-one stones to the opal and turquoise, which are but three fifths as hard. The test for hardness is made by scratching the stone to be tested with every other stone until one is found which will neither scratch nor be scratched by the other. These two stones, it will then be readily seen, must be alike in hardness. In making this test great care must be taken not to scratch the facets, or faces, of the stone; generally a trained lapidary (expert in gems) will recognize the quality by the merest touch on the edge of the gem. Another test used is to weigh the jewel against an equal amount of water; and still another test may be made by chemical solutions which act in specific ways upon certain gems. But if a gem answers satisfactorily to all these tests there is still the chance of its value being lessened by flaws — that is, by having some foreign substance or defect embedded in it. In cutting gems the lapidary always tries to cut off these flaws, or to cut the stone in such a way that they will mar the beauty of the jewel as little as possible.

HOW GEMS ARE CUT

It was not until a comparatively recent date that people found out how to cut gems in such a way that it would bring out the greatest beauty in them. The ancients had no knowledge of crystals or of minerals, and therefore they either wore their jewels uncut, or they cut them in a crude fashion quite regardless of their real formation. Sometime in the fifteenth century, however, a gem-cutter from Bruges discovered that a diamond could be made far more brilliant by so arranging its facets that the light would reflect through them and split into prismatic rays. Immediately the finest gems were sent to Bruges for cutting, and the place became the center of the industry; but after the death of Van Berquen, this famous gem-cutter, his workmen scattered to Amsterdam, Antwerp, and Paris, and these cities in turn became well known for their work. Now there are gem-cutting establishments in England and the United States as well. In all these places, however, the same methods are followed as were in use so many years ago.

There are three operations necessary in cutting a diamond — "bruting," "polishing," and "cleaving." In bruting a diamond another diamond is used. Each stone is first cemented into a holder and then the two are rubbed together until the constant friction changes the shape of the one to be cut to the form desired. During this process a fine diamond powder, much like that from a slate pencil, is ground off and falls into a sieve beneath; this powder is later used to polish the stone. The stone, having now been shaped, is ready to be polished, and it is therefore taken from the holder into which it was cemented for bruting and is soldered into a cone of tin and lead called a "dop." The small flat facets are then polished off by a revolving wheel or "skeif." If the stone becomes so hot from the friction that the dop in which it is held is in danger of being melted the whole thing is plunged now and then into cold water.

The three forms for cutting gems are known as the "brilliant," the "rose," and the "briolette." Most valuable stones are cut in the brilliant, an octagonal surface surrounded by thirty-two facets reaching from the edge of the stone towards the center. At the back there are twenty-four facets which mount upward in a pyramid form; the apex of this pyramid, however, is smoothed off parallel to the front face, or table, of the stone. Rose cutting is used only for thin or small stones, and the gem is left perfectly flat on the back and cut in triangular facets of equal size on the front. The briolette cutting is seen on most pendants and jewels of pear-shaped form, the surface of such gems

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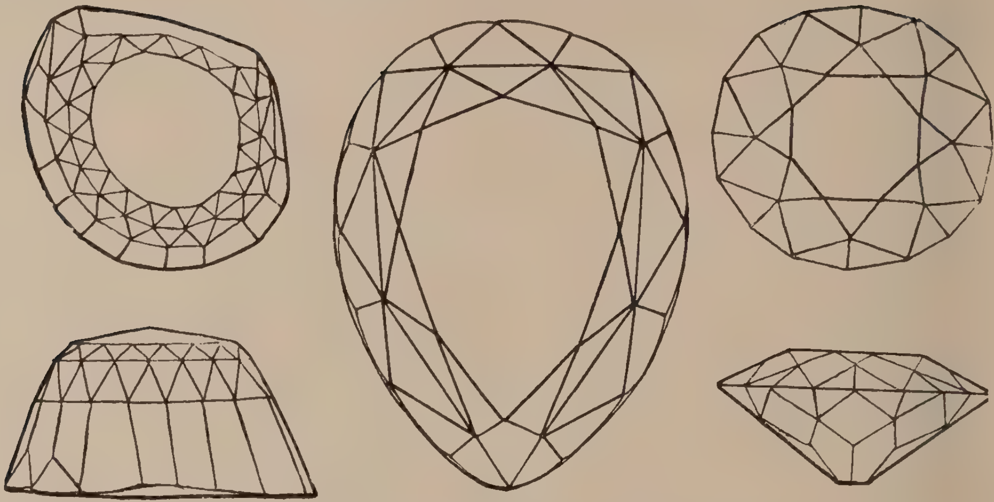
SORTING THE ROUGH DIAMONDS, DE BEERS MINES, KIMBERLEY, SOUTH AFRICA



THE SHAPE AND FACETS OF THREE FAMOUS DIAMONDS

Left: Top and side view of Orloff diamond. Center: The larger of the two sections of the Cullinan diamond. Right: Top and side view of the Koh-i-noor. [Illustrations on pages 302, 303, and 304 from "Gem Stones," James Pott & Co., N. Y.]

being cut in a great number of tiny triangular faces.

When gems are very irregular in shape or are marred by serious imperfections, large sections of them must sometimes be taken off, and this is done by splitting the stone in the direction of its natural cleavage. You all know how wood will split with the grain. The same law holds good with crystals. They have a natural tendency to break off in the line of their planes, or faces. Here again the workman must have a knowledge of crystallography.

Working at diamonds requires much strength, while the work on softer stones must be more delicate. Most transparent stones are cut in brilliants, but the emerald is an exception to this law, being cut square or oblong. Stones such as the opal and moonstone are polished off with a curved surface.

HOW DIAMONDS WERE DISCOVERED IN SOUTH AFRICA

At the present time most of our diamonds come from the mines of South Africa. Here there are diamond-bearing veins of earth which are worked by sinking shafts just as we do for coal. After this earth is taken from the mine it is sent to a washing-plant where the heavier part which contains the diamonds is separated and sent on through various machines until everything is drained off except the diamond-bearing gravel; from this the gems can be picked out by hand or removed by machinery. Many diamonds are found in the sand of rivers coming from diamond-bearing localities, and often men who wash this soil by hand find in it valuable stones.

It was pure chance that led to the finding of diamonds in South Africa. Some children who were playing along a tiny stream not far from Cape Town and Kimberley found on the shore a sparkling stone which they carried home. One day an old friend of the family happened in and the children's mother hunted up the stone from the back yard and showed it to him. The man did not think it was of value, but as a joke he offered to buy it. To this the mother would not listen; instead she insisted upon giving it to him, saying laughingly, "Take it and make your fortune!" The man, Van Niekirk, carried the stone away and let his friend O'Reilly take it. O'Reilly carried it about in his pocket for some time, amusing himself now and then by scratching his name with it on the window-glass; then one day he put it into an ordinary envelope and sent it off by mail to a Dr. Atherstone, who was a mineralogist. This scientist was quite sure that the stone was a diamond and asked the opinion of another mineralogist concerning it. In 1867, at the suggestion of the Colonial Secretary, the stone was sent to the Paris Exhibition, where it was declared by a great number of scientists to be a diamond. Later Van Niekirk bought from the natives other stones, and one of these he sold for over fifty thousand dollars. This diamond is the now well-known "Star of South Africa." Thus did the tide of the diamond industry move to Kimberley. There are also very valuable diamond mines in India, Brazil, Borneo, British Guiana, and Australia.

SOME FAMOUS DIAMONDS

Some of the largest and most famous diamonds of the world are the Great Mogul, 279 carats; the Excelsior, 239 carats; the Orloff, 193 carats; the Koh-i-noor, 186 carats; the Star of the South, 125 carats, and the giant Cullinan, which has been cleaved into two parts, one weighing 516 carats, the other 309 carats, besides a number of smaller stones.

INDIAN LAPIDARY

The Koh-i-noor, like the wonderful "Black Prince's Ruby" and the Cullinan, are among the crown jewels of Great Britain. Austria, too, possesses magnificent crown jewels, less celebrated for their size, perhaps, than for the delicacy and beauty of their settings. One set of many pieces in a rose design is especially charming, the flowers and buds being made from rubies, and the leaves and stems from diamonds.

FRENCH FAMILY CUTTING STONES

STONES OF OTHER KINDS

The ruby, sapphire, oriental emerald, oriental topaz, and oriental amethyst all belong to the same general family, but their difference in color makes a vast difference in their value. The rubies from Burma, Siam, and Ceylon are the finest, although the Burmese rubies far surpass the others in color. The sapphire is the chief gem of value to be found in the United States; some stones of most beautiful cornflower blue, coming from Montana, rank as the finest in the world. Emeralds come from Africa, Asia, Australia, and North America, but the greatest number are found in South America—Colombia and Peru. There are also numerous semi-precious stones, such as lapis lazuli, jade, and agate, found in quantities in Switzerland, Russia, China, and Japan (For further information on precious stones see the section on "Precious Stones and Gems" in Volume I, pages 187–191.)

At present many artificial gems are manufactured in laboratories and conform to almost every test of the genuine stone. The art of making small crystals was discovered by Gau-

NATIVES DRILLING PEARLS

For use in necklaces and pendants pearls are bored with a steel drill and threaded with silk, an easy operation on account of their softness. These are called "seed pearls."

din in 1837 and was further perfected in 1877 by two Frenchmen who succeeded in making crystals large enough to cut. Since then, many manufactured gems, some of them wonderfully beautiful, have been made; among them are the Tecla pearls, which can be told from real pearls only by an expert. (For further information on pearls see "Fisheries.")

A NATIVE RUBY MARKET AT MOGOK, UPPER BURMA, A CITY BUILT AROUND THE RICHEST RUBY MINES IN THE WORLD

Photographs copyright, Underwood & Underwood

RUBY CUTTING IN A NATIVE SHOP, WITH RUDE TOOLS, BUT PRODUCING REMARKABLE GEMS, IN THE FAMOUS MINES, MOGOK, BURMA

PROSPECTING IRON ORE IN LAKE SUPERIOR REGION

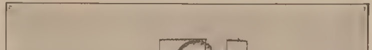
THE MAKING OF STEEL[1]

STEEL is a product which enters into human needs more generally than almost anything else; yet strange as it may seem, comparatively little is known by most people of its manufacture. Doubtless we have handled many articles made of this material, but how many of us have actually seen the manufacturing operations?

The first step in steel making is the smelting of ore into pig iron, by which name it is called whether it is in the molten state or cast into pigs or bars. The second stage is the purification or refining of the pig iron into steel. This transforms the brittle pig iron into the malleable, ductile (look up these two words in the dictionary) steel that can be hammered, rolled, drawn, and fashioned into many shapes and forms.

HOW DO WE GET STEEL FROM PIG IRON?

The two processes most commonly used in this country for transforming pig iron into steel are the *Bessemer* and the *Open Hearth* methods, each of which is divided into two classes: the Acid and Basic Bessemer, and the Acid and Basic Open Hearth. The Acid process is used where carbon, silicon, and manganese are to be reduced in quantity; the Basic where in addition to these three chemicals there is an excess of phosphorus and sulphur to be taken out of the raw material. In the Bessemer process only pig iron is used as a raw material; in the Open Hearth process both pig iron and



OVERHEAD WORKS OF AN ORE SHAFT MINE

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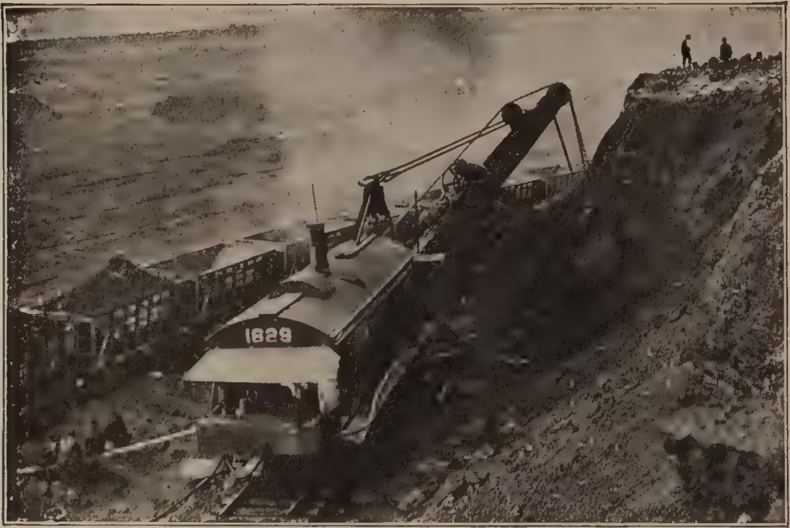
[1] The material for this article and also the pictures accompanying it are used by the kind permission of Mr. John W. Meaker, of the American Steel and Wire Company, Chicago, a division of the United States Steel Corporation.



VIEW OF AN OPEN MINE, WITH STEAM SHOVEL, SHOWING EXTENT OF WORKINGS

scrap (old pieces of wrought iron) may be used.

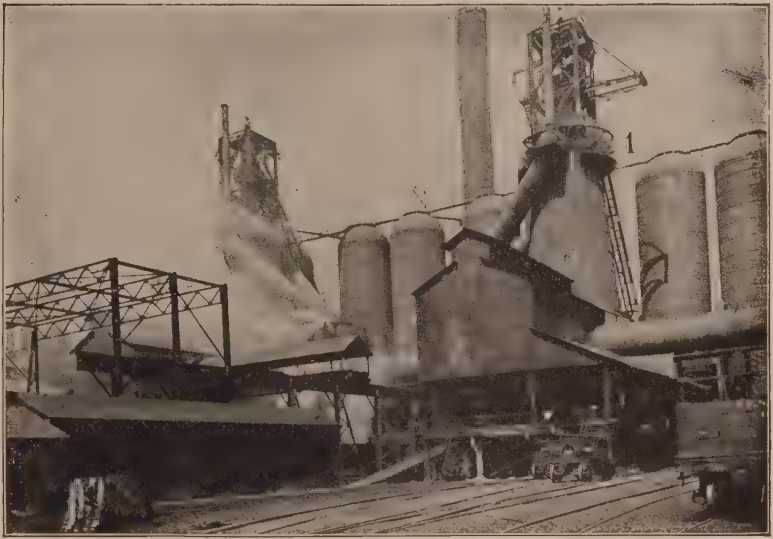
In both the Bessemer and Open Hearth methods the impurities of the pig iron are burned out by bringing air into contact with the molten iron. In the Bessemer process this is done by blowing a blast of air from the bottom through the kettle of molten metal. In the Open Hearth process air passes over the top of the molten bath, and the impurities are either consumed or absorbed in the slag as they rise to the surface. In the Bessemer process enough heat is generated by the burning of the impurities to maintain the bath at a proper temperature. In the Open Hearth process it is necessary to maintain the bath at molten heat from an outside source. Some manufacturers claim the superiority of one method, some the other.

Beginning with prospecting for ore, the pictures will show the transporting of the ore to the blast furnaces, and the making of that ore into billets ready to be shipped for manufacture. It is wonderful to see how every detail has been worked out to secure economy.

GETTING OUT THE ORE FROM THE EARTH

Ore mines are very different from coal mines. Coal is found in an even stratum or layer at a certain distance below ground, and the vein extends over a wide area, while iron ore is massed in a great body in one place, making prospecting more difficult. The most important iron ore deposits in this country are found in the Gogebic and Menominee ranges south of

LOADING BOATS WITH IRON ORE



GENERAL VIEW OF BLAST FURNACE

Lake Superior, and the Vermillion and Missabe ranges north of Lake Superior.

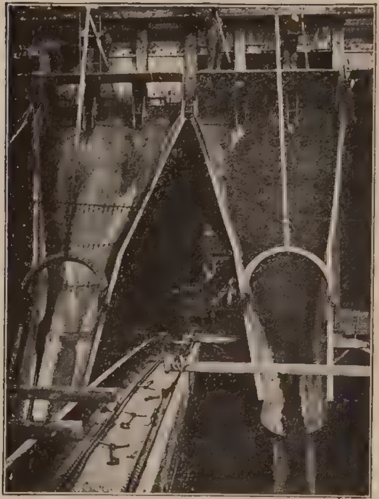
Sometimes the ore body is very near the surface, and the ore can be mined by steam shovels. Such a mine is exceptionally valuable, because of the ease and cheapness with which the ore can be gotten out.

As the ores differ in character, they are usually kept separate until they reach the blast furnace, where they can be properly mixed for the particular make of steel required. If you ask why the ore is not reduced to pig iron in the region where it is found instead of being hauled to Illinois, Ohio, or Pennsylvania, the answer is that it requires coal, coke, and limestone to reduce the ore, and it is cheaper to transport the ore to the coal and limestone regions than to carry the coal and limestone to the iron ore beds.

FROM MINE TO MILLS

The ore is loaded on cars at the mines and taken to the docks from which the ore vessels are loaded. These docks are perhaps seventy-five feet above the water. The train loads of ore are run out on the top of the docks and the ore is dumped into pockets from which it passes through chutes into the hold of the vessel. This is one of the great industries of the Lake Superior region, and makes the city of Duluth an important

UNLOADING ORE AT FOOT OF LAKE MICHIGAN

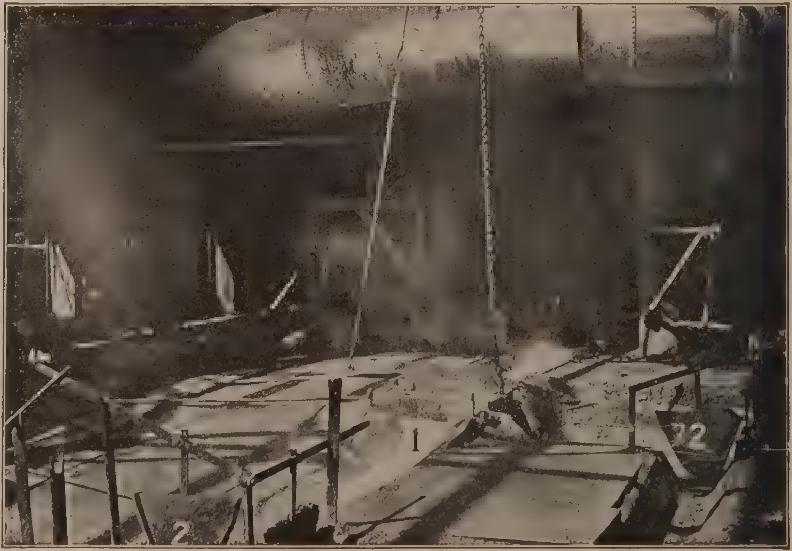


CHUTES LOADING ORE INTO VESSELS

DRAWING OFF SLAG FROM BASE OF BLAST FURNACE

shipping point. The modern ore boats are about six hundred feet long and sixty feet wide, their length, width, and cargo being regulated by the locks at the Soo through which they have to pass to get into Lake Michigan. There are two canals and locks on the American side of the Soo River, and one on the Canadian side, the latter newer, larger, and deeper. There is no charge for passing through these locks. A boat of the size given will carry about 10,700 tons of ore. There are often from fifty to seventy-five boats at the Soo waiting their turn. The Steel Corporation has a fleet of over a hundred ore-carrying boats, and maintains a supply boat at the Soo, which delivers supplies, food, and orders, and takes off mail and dispatches, while the larger boats are under way, so that they do not have to stop for this service.

Having brought the ore down to the foot of Lake Michigan or to some Lake Erie port, the unloading is done by hoists, — the ore being hauled out by clamshell buckets, which run back upon the runway and dump the ore into the cars, if for a distant furnace, or carry it to the ore piles beyond, if it is to be smelted at that point. All this machinery works with a precision that seems almost human in its movement.



DRAWING MOLTEN PIG IRON FROM BLAST FURNACE

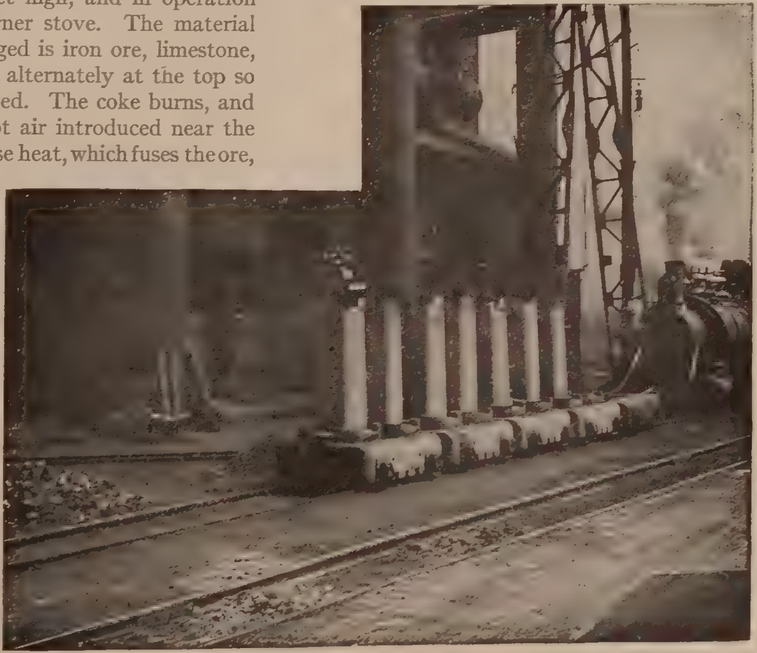
BESSEMER CONVERTER READY TO RECEIVE MOLTEN PIG IRON

AT THE BLAST FURNACE

The next step is at the blast furnace, which may be regarded as a very large stove seventy-five to a hundred feet high, and in operation similar to a base-burner stove. The material with which it is charged is iron ore, limestone, and coke, dumped in alternately at the top so as to be properly mixed. The coke burns, and under the blast of hot air introduced near the bottom gives an intense heat, which fuses the ore, causing the metallic iron to separate and collect at the bottom as it trickles down through the mass. The separation of the iron from the dirt and earthy impurities is possible because the latter combine with the limestone to form a fluid slag lighter than the molten iron. This slag therefore floats on the top and can be drawn off. The hot metal is tapped into kettles, known as "ladles," and carried in them to the Bessemer converter or Open Hearth furnace. All this is pretty hot work, and if you visit a blast furnace plant you will not soon forget it, nor cease to wonder how men can stand the intense heat. When the slag or metal is drawn off it makes you think of the infernal regions.

WHERE THE NAME PIG IRON CAME FROM

Why do they call the iron billets "pig iron"? Mr. Meaker tells us. In former times it was the custom to dig ditches or sluiceways in a sand floor, and from the main ditch smaller ditches or slips were dug on either side, these being about two feet long. The molten iron flowed down to the main ditch and into the small ones, where it cooled and was broken up into the bars with which you are familiar. It was because these smaller ditches on each side of the main one looked something like a litter of pigs with the mother that the name pig iron arose. In the modern process the hot



A TRAIN OF INGOTS

ROLLING AN INGOT INTO A BLOOM

metal is carried directly to the furnace to be purified into steel, thus saving the cost of re-melting. The blast furnace is tapped five or six times in twenty-four hours, and about eighty tons of molten pig iron are drawn off each time. A ladle will hold from twenty to forty tons of metal.

WHAT THE BESSEMER CONVERTER DOES

You see the converter tipped over to receive a charge of molten pig iron. It will take from ten to fifteen tons at one time. As soon as it is charged, a blast of air is started through the bottom of the kettle, which is then turned upright. The air bubbles through the molten metal just as you can blow air through a straw into a glass of water. The oxygen of this air blast consumes the impurities of the pig iron. The remaining earthy impurities gather at the top in the form of slag, and the carbon, silicon, and manganese burn in the form of a gas above the converter, making the beautiful colored flames which illuminate the night when a Bessemer-furnace is in operation. The burning of these impurities, especially the silicon, keeps the bath in a molten state and increases its temperature. When the blast is first started immense quantities of black smoke and red flame come out of the top. It takes twelve to fifteen minutes to cook or purify the metal in the converter. Gradually the smoke ceases and the red flame turns to a whiter color. By the color of this flame the expert tells when the charge is purified. As a safeguard, the chemical analysis of each heat is made and a record of it kept, so that the analysis of the steel is known to a certainty.

When the operation is completed, the purified steel is poured from the converter into the kettle, which is lowered into a pit to receive its load and then raised and swung around so that its contents can be poured into the ingot molds. As soon as cast these are hauled to the rolling mill. A heated ingot is eighteen inches square by five feet long and weighs five thousand

REDUCING A BLOOM INTO BILLETS

pounds. It is now ready to be rolled down to a smaller size and longer length, for out of these ingots the steel rails for our railroads come.

At this point the steel might be run through a pair of V-shaped rolls and become an angle iron, or run through suitably shaped rolls and made into an I-beam or a railroad rail. One of the most interesting parts of the process is the rolling of an ingot into a bloom, and then reducing a bloom into billets, or four-foot lengths four inches through.

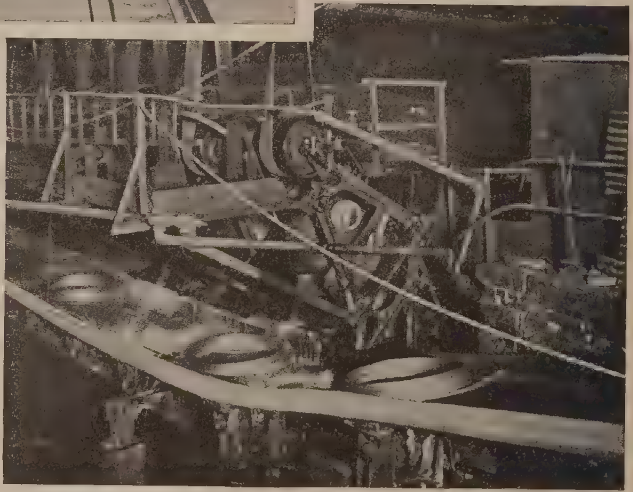
Sheared into billets, the steel is in marketable form, and is carried while still at a red heat out into the yard, where it is dumped for loading into cars. We have now followed the iron ore from the mine to the finished steel, in the form ready for various factories to receive it and manufacture it into all kinds of desired products, from a needle to a massive girder. Not only are we indebted to Mr. Meaker for the foregoing sketch, but it is also through his kindness that we are able to give the description of wire making which follows.

THE MAKING OF WIRE

WIRE of every sort is made from steel which is received at the wire mills in the form of billets. These billets are bars of cold steel and therefore, before the rolling process can be taken up, which is the first step in making them into wire, they must be reheated in a reheating furnace. Then the billet is conveyed automatically to a set of rolls, through which it is passed from one size to another, until what started as a redhot billet four inches square is rolled down to a rod, No. 5 gauge, or smaller than a lead pencil. This requires very skillful handling. The rod, still hot, is now conveyed through a pipe to a coiling device, which coils the rod until the bundle is completed, then dumps it on to a moving platform below. This carries the bundles through the open air, which cools them, so that they can be loaded into cars for shipment to the wire-drawing plant. This is the end of the hot rolling, and from this

CONTINUATION OF ROD REDUCTION TO LEAD PENCIL SIZE

point on the steel is drawn cold into wire of all sizes. First the black scale, or coating formed in the heating process, must be removed by an acid bath; then a "sull coat" of slightly greenish hue is put on by running the bundles slowly under sprays of water; next follows a dipping in milk of lime, which puts on a white coat, neutralizes any remaining traces of acid, and protects the rod from further atmospheric action, besides acting as a lubricant when the rod is drawn through the steel die. The lime-coated rods are put in an oven and baked for several hours at a temperature of about four hundred degrees, and are then transported to the wire-drawing department.



COILING RODS AND DUMPING BUNDLES TO PLATFORM

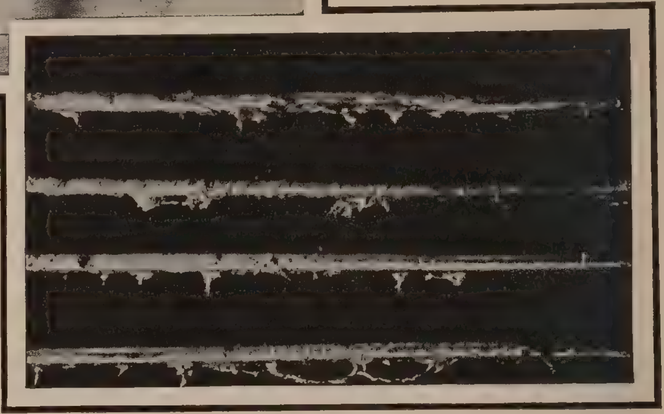
LOADING PLATFORM FOR SHIPMENT OF RODS TO WIRE MILL

The pictures show the operations which follow. The rod enters one of the larger holes in the die (see p. 318), passes through, and comes out of the smaller hole on the other side. This drawing process continues until the required size is reached. As you see, the wire is crooked when it leaves the spindle (1, in lower illustration, p. 313), but it becomes wire, round, smooth, and without kinks, after it has passed through the die

IMMENSE OVENS FOR BAKING THE RODS

SHOWING ACTUAL WIRE-DRAWING OPERATION

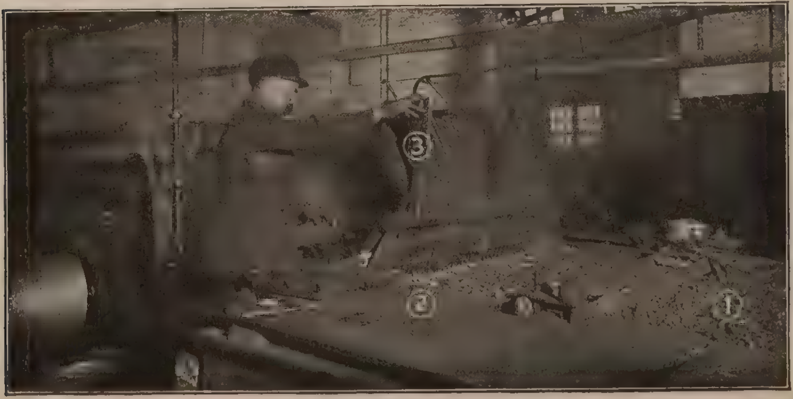
PAIR OF ASBESTOS PLUGS



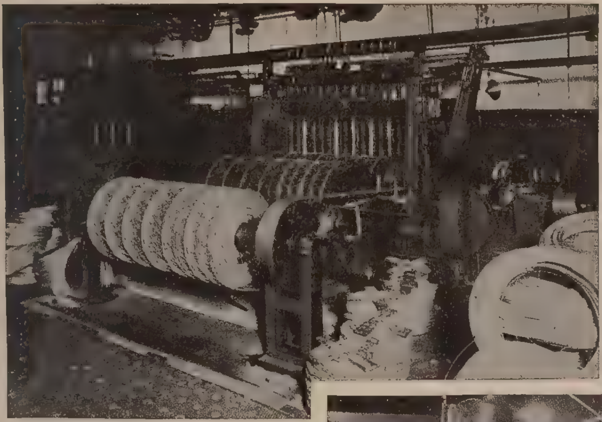
GALVANIZED WIRE AS IT WOULD APPEAR IF NOT WIPED BETWEEN ASBESTOS PLUGS

(2). The dies have to be repaired frequently.

The galvanizing process is another interesting step in wire making. First comes the "annealing," or heating and cooling until the metal is made soft and tough, which is done by passing the wire through ducts in a furnace, or else by passing it through pans of molten lead, the more common way. Another "pickling" or acid bath is now necessary to remove the black scale, as the wire must be chemically clean before the zinc of the galvanizing bath will attach itself to the wire. You see what care has to be used at every point. The wire is now run through the kettle of molten zinc at such a speed as will heat the wire to the temperature of the zinc before it comes out. Manufacturers who claim double or triple galvanizing only mislead the purchaser, for no one practices double galvanizing, for the sufficient reason that it cannot be done, since a second bath would melt off the first one. The galvanizing done by one maker is better than that of another only because one manufacturer exercises greater care than another. After the galvanized wire is wiped between asbestos plugs, to make it



GALVANIZING OR COATING WIRE WITH ZINC



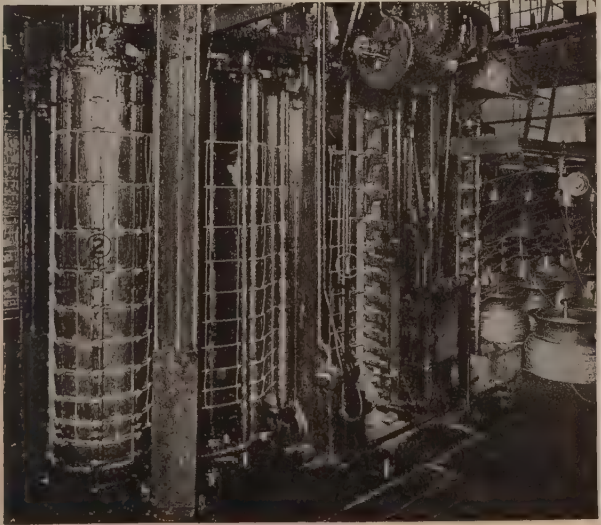
MACHINE MAKING WOVEN WIRE FENCE — REAR VIEW

even, it is ready to be coiled up into commercial bundles. In this form it is shipped to the trade, for use in the manufacture of woven wire fence, barbed wire, or other commodities. To keep the product up to the standard of strength and thickness of galvanizing coat, a piece of wire is taken from each galvanizing pan once every hour and sent to the laboratory to be tested.

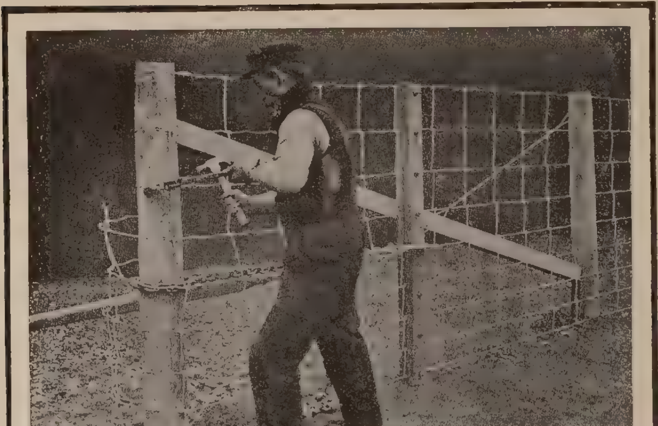
WIRE BUNDLES AT BACK OF A BANK OF FENCE MACHINES

BARBED WIRE AND WOVEN WIRE FENCE

If you have tried to climb through a barbed wire fence you will like to know how that peculiar enemy of clothes and skin is made, and will be glad of the chance to look into the barbed wire room, where a machine is turning out the galvanized barbed wire. Two strands are introduced at the back of the machine. The wire which forms the barb is led in from another coil at the side, and the barb is put upon only one of the strands. This wire with the barb upon it passes over a wheel, and is joined there by the barbless



THE WEAVING MACHINE



SPLICING TO LINE WIRE AND STAPLING

THE COMPLETED FENCE

strand, the two coming out parallel at the bottom of another wheel, but not twisted together. They are twisted as they are being wound upon the reel located under the machine.

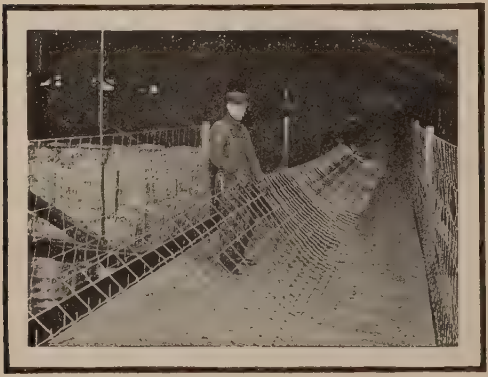
The photographs also show the making of woven wire fence, of the square mesh and other patterns. This is a most ingenious process, which has been carried to great perfection. After you have studied these pictures you will certainly find a new interest in a wire fence whenever you see one, and in all the articles in which wire is used, for you know now how the wire is produced from the pig iron and the steel billets on to the finest wire thread.

MANUFACTURE OF CHAINS

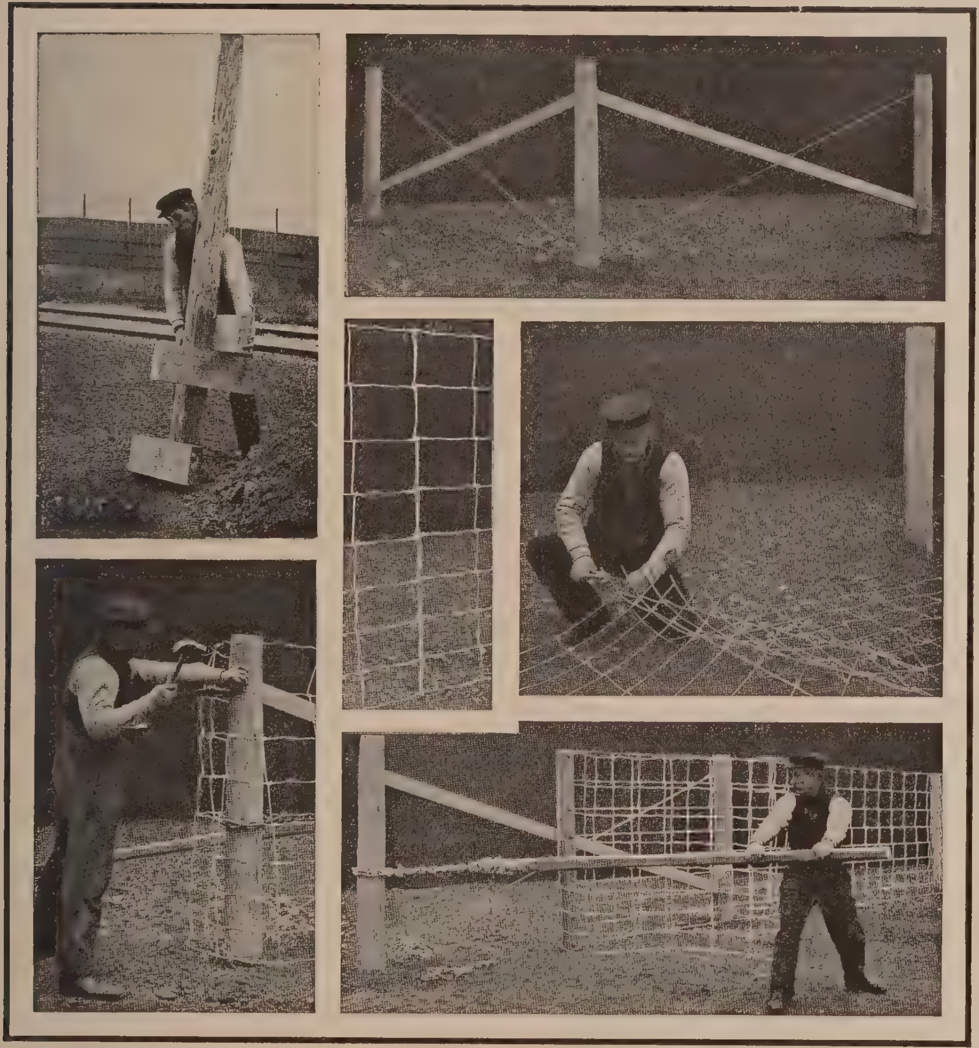
There is a great variety in the kinds of chains manufactured. There are steel anchor chains for large ocean steamers, each link weighing thousands of pounds, and made by steam hammers and presses.

Then come chains for cranes and tackles, some as thick through as a man's body, others smaller and only about the size of his arm. Still others range from the thickness of a pencil to the fineness of a watch chain.

All these are made by machines. One such machine is pictured in the accompanying cuts. After the wire has been fed by the machine, it is stuck through the last completed link, and then cut off by a chisel coming from the left. The first picture shows how the



INSPECTING A COMPLETED ROLL OF WOVEN WIRE FENCE



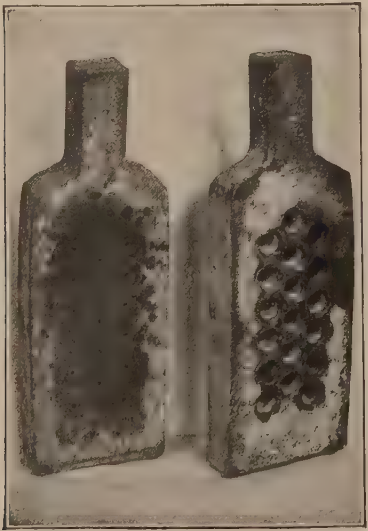
PUTTING UP A WIRE FENCE

Here we see one of the most familiar uses to which wire is put. In the center is a section of wire fencing as it comes from the factory to the man who is to put it up. He digs his hole, a deep one, as the pull on it will be heavy, and anchors the post in this depression which he has made. It is not sufficient merely to anchor the end post, but because of the strain upon it, this post must also be braced. One of the best methods of bracing posts is here shown, with a wooden brace in one direction, and a wire which can be twisted to tighten it in the other. At the corner of the fence it must be braced in both directions. Where two rolls of wire join they must be carefully and strongly spliced. The picture shows the man doing this. Then the wire must be stapled to the post, and the fence finally be stretched taut, as shown in the last view.

In this picture the piece of wire resembling a U is bent to a finished link by the fingerlike parts of the machine, which is a remarkable piece of mechanism.

Here the hook is finished and placed in the right position for the insertion of the next piece of wire by a little hook coming down at the proper moment.

piece of wire is bent first into the shape of a U and then closed by the fingers of the machine to a complete O. In the second picture we see the link finished in the little hook that comes down into position for the next piece of wire to catch into. To make the individual links stronger, an electric soldering or welding apparatus is built into the machine, which in a fraction of a second makes each link one solid ring.



A WIRE-DRAWING DIE

BRASS

BRASS and its many manufactured products form one of the chief outputs of the State of Connecticut. In the United States such a vast supply of metal is found that there is ample material for the manufacturer. Brass itself, however, is not a metal in the strictest sense, but is an alloy made of about seventy per cent of copper and thirty per cent of zinc. The greater the quantity of zinc the lighter will be the color, and the more brittle the alloy, while a larger amount of copper makes the material redder and tougher. This blending of the two substances results in a product widely different from either of them. It was only after much experimenting that men found out just what proportion of each to put in to get the best results.

Brass is a very hard, strong metal which will take a high polish. It is used for house fittings, such as knobs, screws, hooks, and ornamental nails, as well as for the more decorative purposes of making candlesticks, bowls, vases, teakettles, and clocks. Each year at great foundries in Connecticut thousands of clocks are made and shipped all over our country. This industry annually brings a large revenue into the state.

Russia, too, is famous for its beautiful work in brass, and we see in America many exquisite bowls, candlesticks, and ikons, which have been imported.

TIN

TIN is not usually considered a precious metal. Yet tin ranked with gold in those early days of exploration when sailors from the Mediterranean Sea were venturing forth into unknown waters for the treasure which they might bring back. The British Isles were sought as the "Tin Isles" before they were ever annexed by Rome for military purposes. The miners of Cornwall were probably bartering their precious metal for bright-colored cloth from the South hundreds of years before Cæsar crossed the English Channel to see what manner of men these unknown Northerners might be. Tin was precious in those days because, by one of the strange freaks of Nature, this soft substance when mixed with another soft metal, copper, made the metal bronze which was harder than either and harder, too, than any other metal known for many centuries. For this reason bronze was in great demand for swords and ploughshares, cooking utensils, and ornaments, and a whole period in the world's history is known as the "Bronze Age." But there could never have been a bronze age without tin.

THE STORY OF THE TIN CAN

We need look back only a little over a century to find a world in which the tin can was not only unknown but most earnestly desired. In 1800 Napoleon and the French Government were offering twelve thousand francs for a method which should preserve foods in wartime.

Over in England a mechanic named Peter Durand was working on tin containers for food. In 1807 he put on exhibition his first tin can, a heavy and clumsy article, but still a tin can. It was patented, and within a few years two American manufacturers learned the art and began to manufacture cans like Durand's in the United States. It was in 1819 that Ezra Dagget and Thomas Kensett began in New York to offer salmon, lobsters, and oysters in tin receptacles, and we may be sure that many a good housewife turned up her nose and spoke with scorn of the idea of eating anything but fish fresh from the sea. The next year two Boston men were canning fruits, and it was in their advertisements, that the "tin cannister" was first announced, the name to be shortened with American speed to the familiar "tin can."

To appreciate what this new invention meant in those days we must go back to Napoleon and his twelve thousand francs, when the preserving of food as we know it was practically undreamt of. François Appert, a French confectioner, was at work on it, and the announcement of the Government prize stirred him to new activity. He had tried many ways of putting away food in glass jars, and finally hit on the idea that if he could completely seal his fruits or vegetables from the air, they came out after weeks or months or years as sweet and unspoiled as they had gone in. It took hundreds of experiments to prove this, but at last he was convinced and was able to convince others. His method was that of all home canning of the present day. He placed his food in containers, covered it with water, sealed and corked it, then placed the container in a bath of water which he gradually brought to boiling point. But, familiar as it is to-day, it was the newest word of science in those days, and for it the Government gladly gave its prize of twelve thousand francs.

Appert did not have the tin can for a container. But when his method became known, it was seen that such a can met the mechanical difficulties of managing the necessary tight sealing of the contents of the container. To-day the canning industry is one of the largest businesses in the United States, involving the use of several millions of dollars annually.

But the profit to the manufacturer is small compared to the great benefit conferred on mankind. Napoleon saw that he could win a war anywhere if he could only carry with him food with which to feed his armies in the enemies' territories. Explorers have been able to make the long journeys to the North and South Poles and still bring back their men in health because they could take with them the necessary variety of food. The products of all the lands of the world may be brought to a single table, and men may live in the barren places of the world's surface and still be kept in comfort and health. Such is the service which has been rendered in our own day by a metal to which little heed is paid, but because of it the man of to-day would be willing to join hands with the ancient bronze maker in considering tin a precious metal.

FUEL FOR POWER

WHEN we build a home with lumber, make a ball from rubber, or shape a china dish, we are doing a bit of creative work. We are taking raw products and fashioning them into desired and useful articles. But when we take wood, coal, and oil and deliberately burn them up, we would seem at first thought to be engaging in a process of destruction rather than of creation. So we would be if we tested all results by the same measuring rod. But when we come to discuss fuel, we are dealing with an output that is measured not in terms of number or bulk of articles created, but in the amount of heat, light, or power produced. A forest fire is wasteful in the extreme, for valuable lumber is used as fuel with no means of directing to good purpose the heat or the light generated as that fuel burns. But should we say the same of the burning of a cord of wood in our stoves or a ton of coal in our furnaces?

Man's primary needs are for food, shelter, and clothing. Fuel ministers directly to the first two. In our northern climate shelter would be of little avail if it were not possible to keep our houses warm, and man would return to the diet of the animal or the most primitive savage if he had to forego the privileges of cooked food. A single hour without street lights or house lights, occasioned by an accident at one of our public utility stations for electricity or gas, brings forcibly to our attention our need for light. Such are the simplest uses of fuel — for heat, for light, for cooking purposes. We substitute more modern equipment for the candles and oil lamps of our grandmothers and great-grandmothers, and new heating systems for their open fires; but all minister to these primary uses of fuel.

FUEL AS THE BASIS OF MODERN INDUSTRY

Modern man, living in an age of machinery, goes far beyond these needs in his use of fuel as an agent in his production of power. Power is what he wants above all things,—power to keep his factories going, his trains running, his steamships traveling across the seas. His ambitions are by no means satisfied by the strength of his own right arm, by the power which he can generate in his own bodily machine. He seeks to release other sources of power and direct them to furnish the means for doing work at his bidding. It is this need of power to run the complicated machinery of man's making which makes fuel the basis of modern industry. It is this need which makes nations and private companies engage in sharp contests for the possession of the oil-producing regions of the Near East and the Far East, and come almost if not quite to open warfare over the coal fields of Europe.

WOOD AS FUEL

Wood, coal, petroleum, and natural gas are the familiar fuels of our modern life. In the early days of the occupation of this country wood was practically the only fuel. Forests were abundant and easy of access. Even to-day it is said that more wood is cut for firewood than for lumber. But as the supply of wood diminishes and as the distances over which it must be transported increase with the gradual taking up of cleared land for agriculture, wood becomes a more expensive fuel.

In comparison with the other fuels mentioned it should be noted that wood is the only one that can be replenished. Wood *can* be grown; it is a natural plant product which renews itself under proper conditions. Minerals cannot be replaced. The mineral wealth of a country is a definitely limited supply, even though it be so enormous in quantity as to seem unlimited, as in these United States. Man cannot increase the stores of coal laid up in past ages; he cannot refill the oil reservoirs when he has drained them of their supply. He can plant trees; he can so limit his cutting as to allow for the natural new growth of the forests to have its chance. Whether it will be worth while when these trees have grown to maturity to use them for fuel instead of for more constructive purposes is a question for the next generation to settle; but every interest of national life demands that our forest areas be replenished as fast as they are cut, both for the supply of wood to be obtained and for the preservation of our water supply which comes from the high wooded areas.

PEAT A LITTLE USED RESOURCE

In this connection it is interesting to know that the United States has an unused fuel supply now in the making in the peat bogs which may be found in several of its regions. Coal and peat are different stages in the same general process (described in Volume XI, page 59) by which organic material, or, in simpler language, plant life, is held under pressure beneath the earth or packed away from the air in swamps so that the carbon in it is kept from combining naturally with the air. The various fuels of which we are speaking are valuable for burning because they are rich in carbon. The act of burning, of combustion, is a chemical process; carbon in the fuel unites with oxygen of the air. A fire will not burn, as we say, without a good draft. It is the coming together of a substance rich in carbon and of air rich in oxygen which makes combustion possible. Our problem is to find carbon compounds which we are willing to turn to this process. Coal is a rich carbon compound, but it has taken centuries upon centuries of time, and earth conditions very different from those of the present day, to produce coal. Peat is of quicker formation and is now in the making in many parts of our country. It may prove a valuable household resource in some future day.

COAL THE FUEL OF TO-DAY

As it was said of the silent and mysterious Lady of the Lake of King Arthur's court that "her great and goodly arms stretched under" all the court to uphold it, so might it be said of coal that its mighty arms stretch under all our modern life to support and uphold it. No one who has lived through the past years of coal strikes, coal shortages, coal commissions, can have failed to get some realizing sense of this basic importance of coal. The householder knows the need of coal as a source of heat and reckons it accordingly. But the business man, the captain of industry, reckons coal in terms of power, since on its use is built up our whole industrial organization.

Photo, Ewing Galloway, N. Y.

A FOREST FIRE PHOTOGRAPHED BY ITS OWN LIGHT
Extremely wasteful, for neither the heat nor the light are turned to any economic use

Again, as in the case of other industries, it is surprising to find out how recent is this universal dependence on coal. Coal was not unknown in the ancient or medieval worlds; but the story of its modern use might be written under the heading of "A Century of Coal." The anthracite fields of Pennsylvania were known and drawn upon for domestic fuel in the late eighteenth century; but in 1825 or thereabouts coal was first used to make steam, and from that point its story runs parallel with that of the steam engine. What the steam engine has done to make transportation possible it has done through the agency of coal. What we owe to the increasing ease of transportation in the past hundred years we owe primarily to coal. Since modern industry and modern commerce depend on the speed and ease with which we shift goods from one part of a country to another and from one part of the world to another we cannot exaggerate the importance of our great national fuel supplies in our modern life. Add to this the fact that coal is essential for the smelting of our supplies of iron and that iron and steel are our leading manufacturing industries, and we have another argument for the preëminence of this fuel.

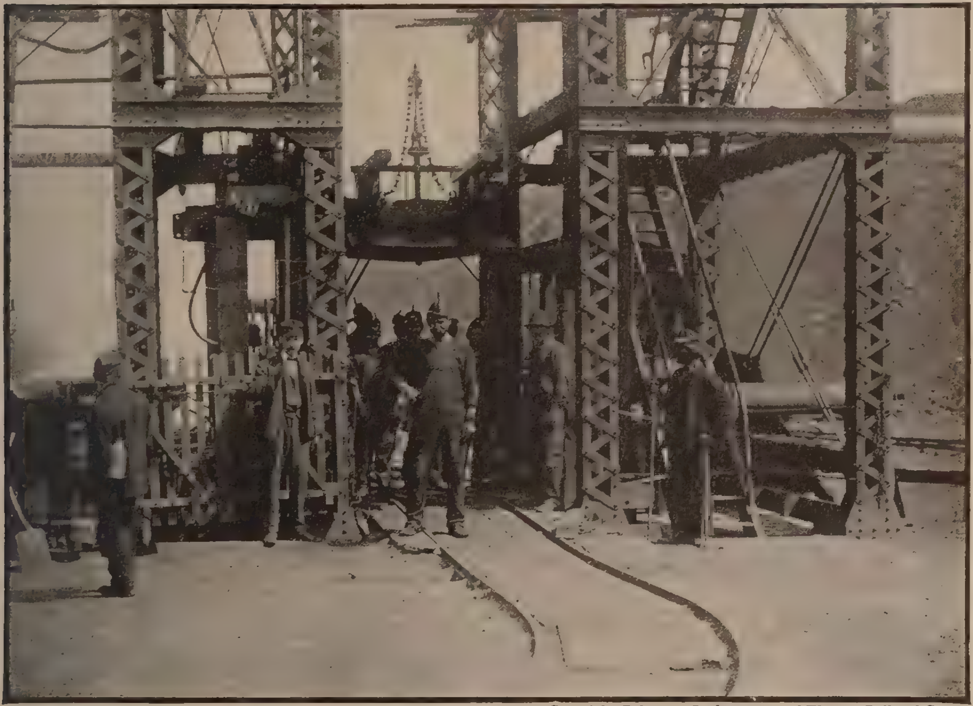
THE COAL INDUSTRY

As an industry in itself the mining and marketing of coal is not unlike other mining enterprises. The anthracite fields of the United States are concentrated in Pennsylvania within an area of five hundred square miles, with only small amounts in Colorado and New Mexico and one or two other fields. The bituminous fields are widely scattered. Professor Bishop describes them thus: "The largest, called the Appalachian, stretches from New York to Alabama, in a southwesterly direction, a distance of nine hundred miles, the field varying in width from thirty to one hundred and eighty miles. The other important fields are the Triassic in Virginia and North Carolina; the Eastern, in Indiana, Illinois, and Kentucky; the Western, including the coal fields west of the Mississippi, south of 43° north latitude, and east of the Rocky Mountains; the Rocky Mountain, comprising the areas in the states of this region; and the Pacific Coast field, embracing the coal regions in Washington, Oregon, and California. The anthracite area of eastern Pennsylvania, together with the bituminous fields of the Appalachians, produced in a recent representative year about seven tenths of the coal output of the United States."

So plentiful has seemed our supply of coal that in the past it has been mined with more or less waste and used without due regard for conservation. Although the United States is still rich beyond other nations in its supply of coal, yet it is learning from its scientists to avoid this waste. When coal was burned to make the more concentrated fuel "coke" in the so-called "beehive oven" of the past, important by-products, like ammonia, tar, and benzol, went off into the air in the form of gases and were lost. The modern coke oven preserves these hydrocarbons and turns them over to the manufacturer for future use. Our whole domestic and factory system of burning "raw coal" without the conservation of valuable by-products and with the relatively small amount of heat produced is said by engineers to be so wasteful as compared with a proper modern power plant, that it is predicted coal will in the future be burned at certain fixed points and the resulting heat or power will be carried long distances with far greater economy than by our present method. At all events it behooves us at this time, when coal is so much under discussion, to gain and apply what information we can as to our own particular use of coal, as these engineers are studying the greater problems of industry to make greater savings or better use of the power produced.

COMPETING FUELS OF THE PRESENT AND FUTURE

So interesting is the story of another natural fuel found beneath the surface of our Mother Earth that we have told of "Petroleum" in its history and in the methods by which it is obtained in a special chapter immediately following. But of petroleum as a competing fuel we must speak here. The United States is rich in this oil, and in certain sections in the "natural gas," said to be the most perfect fuel in the world, which is associated with it, both being the product of the slow decay of plant and animal life of long ago. Petroleum is valuable not only as a fuel oil but for many products



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LANDING AT THE TOP OF THE SHAFT

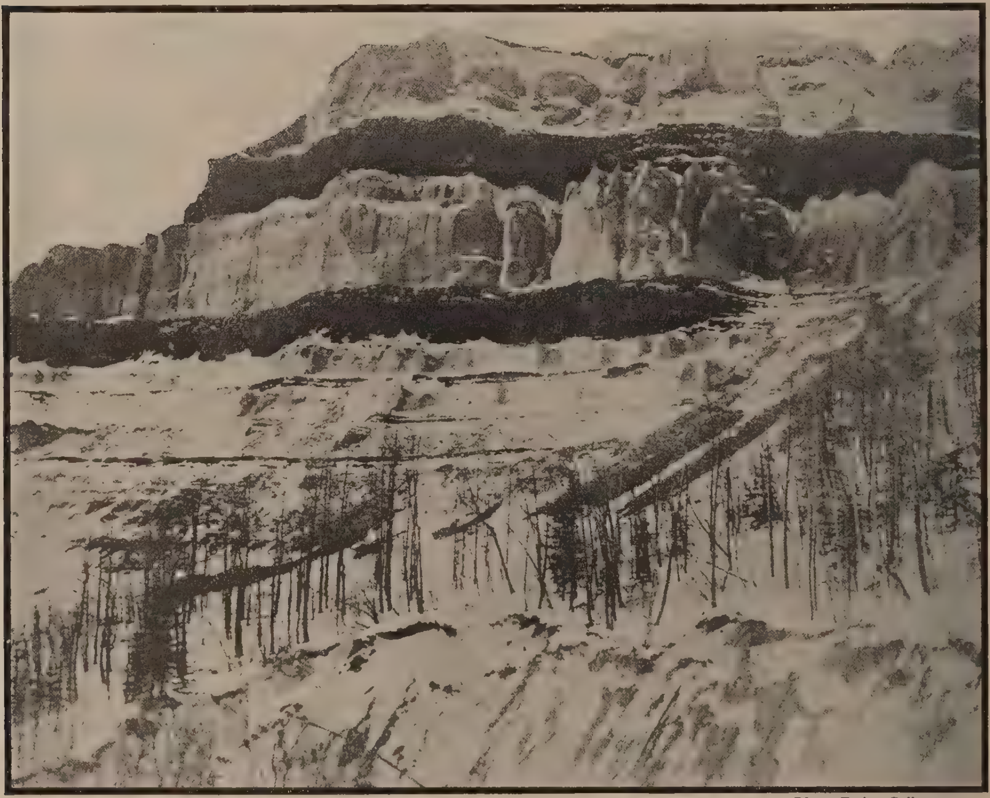
of which it is the source, such as kerosene, gasoline, benzine, naptha, lubricating oils, paraffin, and other less familiar substances which are of importance to the chemist. It has come recently into great demand as a fuel oil in our oil-burning ships and power plants as well as for domestic use. The automobile makes heavy demands on this source of supply for running its engines, and the airplane promises to be equally insistent with its claims. So great is the appreciation at this moment of the present and prospective value of petroleum that nations are engaged in a race to obtain special rights and concessions in those regions which are probably rich in it.

OUR NATION RICH IN ITS RESOURCES

The United States is producing from its own fields a goodly proportion of the world's entire supply of petroleum. It mines from one third to one half of the coal of the world — far more than any other one nation, and almost as much as Germany and Great Britain put together. We take a place second to South Africa in the production of gold. Mexico surpasses us in silver, but we mine it in great quantities; we also produce more lead than any other nation, as well as one fourth of all the zinc. About one third of the iron and one third of the steel consumed comes from the United States. Half the world's supply of copper also comes from this country — Montana, Michigan, and Arizona providing the greater proportion of it. And the mineral wealth of the United States is steadily increasing in the value of its annual product.

FALLING WATER A SUBSTITUTE FOR COAL

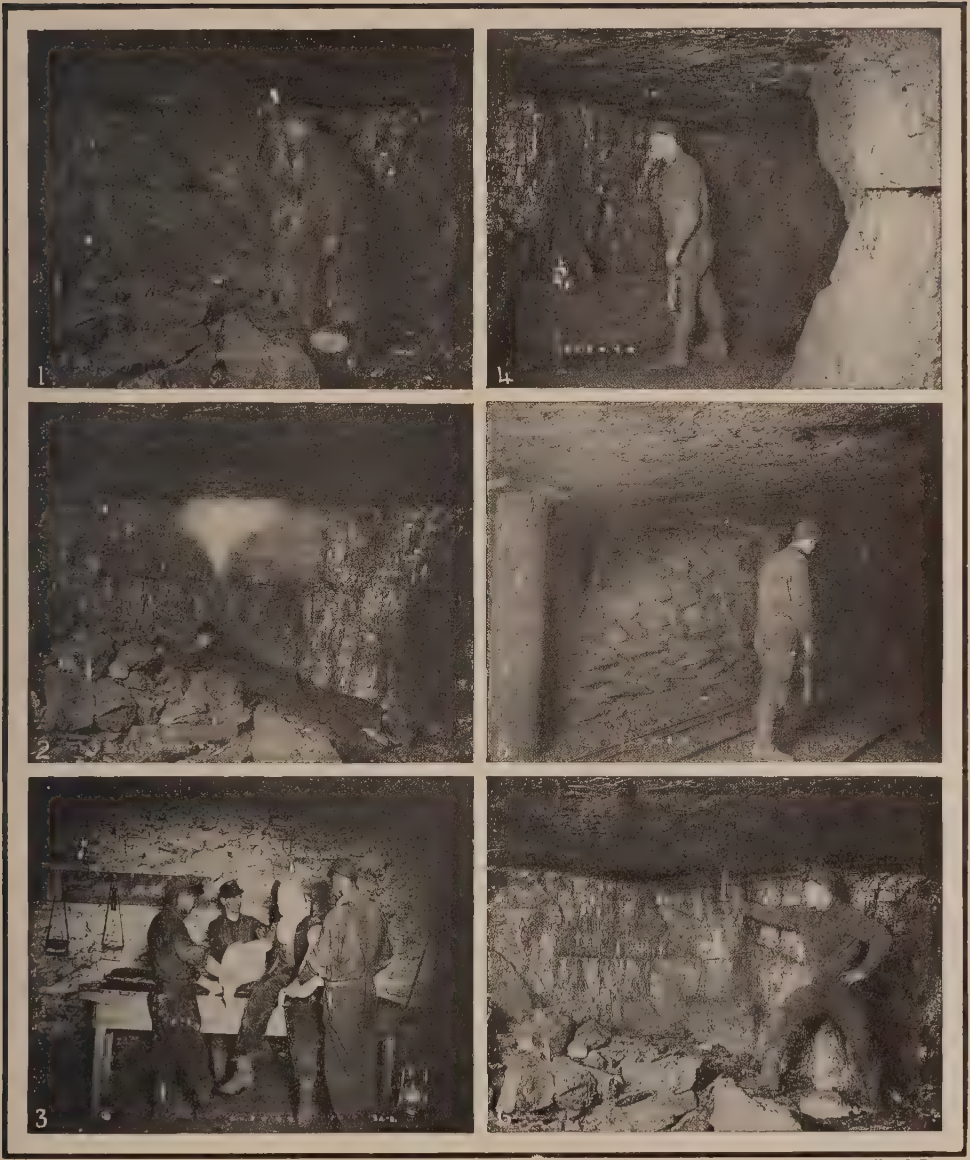
Beyond all these mineral resources stored in the earth is our water power, a natural resource of almost untold value. We have seen how fuel is reckoned in modern industry in terms of the power resulting from its use. In falling water man has a substitute for fuel which if utilized will do much of his work. This water power is particularly useful for the generation of electricity, since hydroelectric electricity is cheaper than that made by coal. With it as a convenient producer of power for local use and with our widely distributed coal and oil fields, it would look as though we were endowed for generations to come with the possibilities for keeping up and increasing our great industrial systems. It is a long day indeed since Queen Elizabeth would have no coal in her palace because of the gas that was given off when it was burned and decreed that only wood should be burned in London during the sessions of Parliament, arguing that the country gentlemen who came into the city were not accustomed to it and it might not be good for their health.



Photo, Ewing Galloway

A MOUNTAIN OF COAL IN ALASKA

While the unexplored and undeveloped regions of the earth hold coal supplies like this, we need not be alarmed at the prospect of exhausting the world's coal supply in our time. Alaska has vast mineral wealth



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SCENES IN A COAL MINE SHOWING THE RIGHT AND WRONG WAY OF WORKING

1. A careless miner holds a naked lamp near the roof without testing for gas with his safety lamp. 2. What happens? He is knocked down and injured by an explosion of gas. 3. He receives first aid treatment. 4. A careful miner leaving coat, dinner pail, and naked lamp at the box, for he, too, is working in a "gassy" chamber. 5. He goes from box to face with only his safety lamp. 6. At the face he tests for gas. His safety lamp burns with a long blue flame, but the miner is safe.

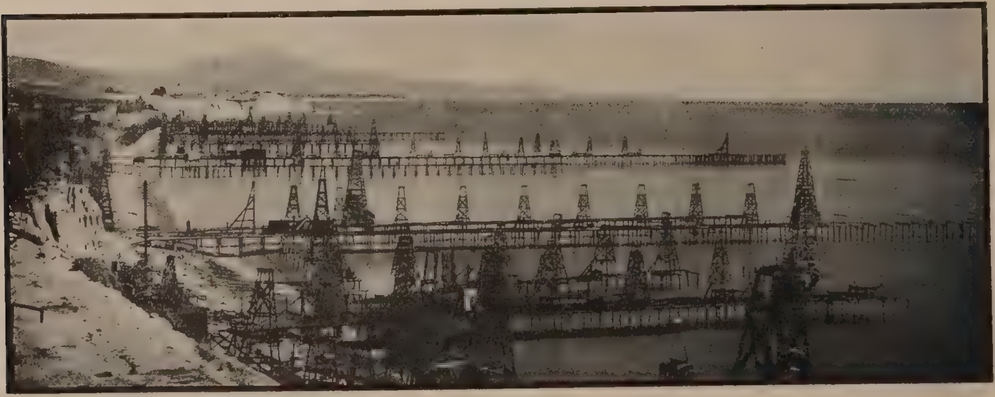
PETROLEUM

WHAT IS PETROLEUM AND WHERE DO WE GET IT?

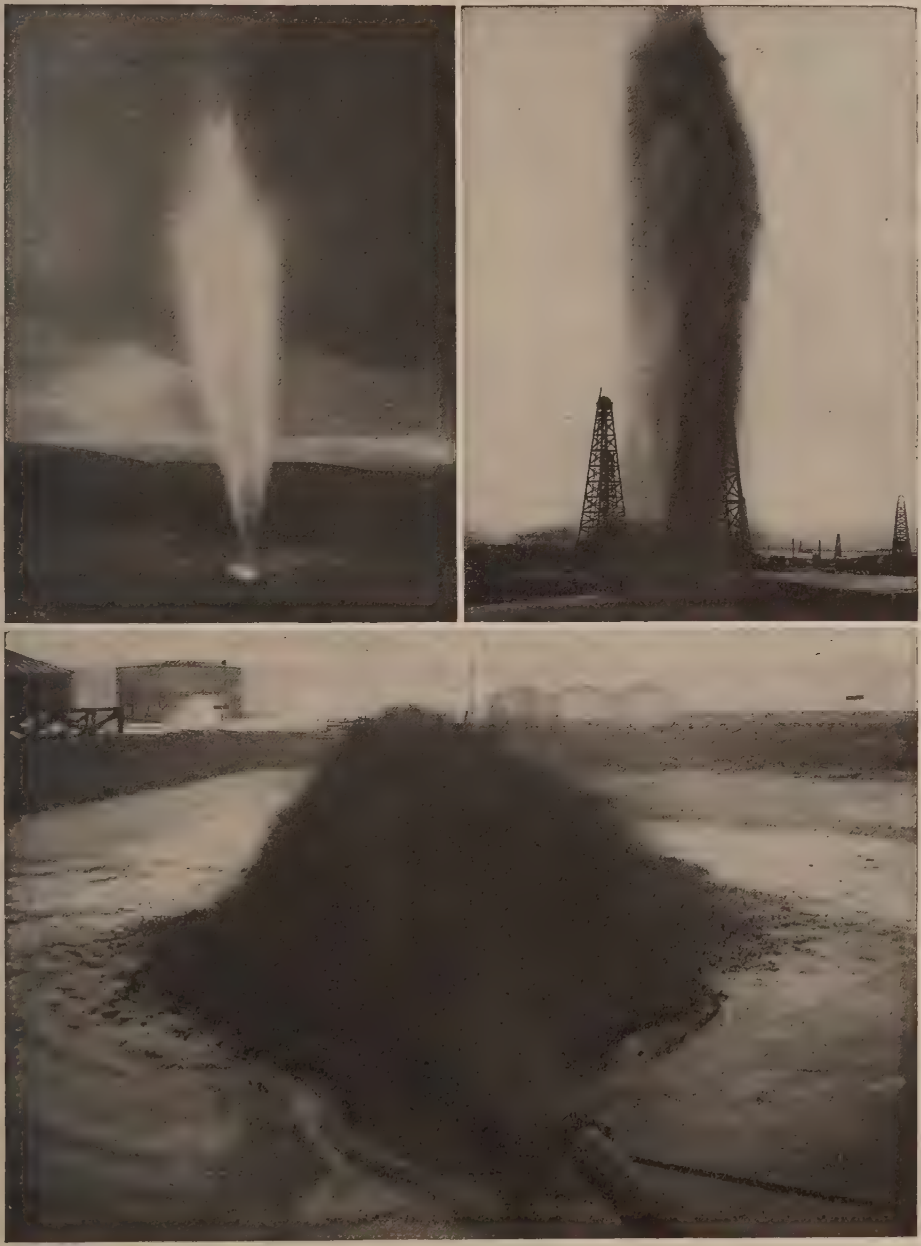
PETROLEUM is a sort of oil found in certain localities by boring into the solid rock. How it gets there and why we do not exactly know. The United States and the land lying about the Caspian Sea have developed their oil products more extensively than any other countries in the world. There are, however, great deposits of oil in China, Siberia, Burma, Asia Minor, Canada, Mexico, and Peru; but as yet these fields have not been opened to commerce, and therefore yield but a small part of the supply that might be taken from them if the modern methods of working oil wells were to be employed.

The uses of this wonderful rock-oil are by no means recent discoveries, for Marco Polo tells us that at Baku on the Caspian Sea there were great spouting springs of oil from which shiploads might be taken, and he adds quaintly: "This oil is not good to use with food but it is good to burn." At a much later period our American Indians found oil of much the same sort in our own country, and after rubbing their bodies with it declared that the tingling sensation caused made them speedier at running.

Yet despite many vague tales of the value



SHORE AT SUMMERLAND, SANTA BARBARA COUNTY, CALIFORNIA, SHOWING OIL WELLS DRILLED UNDER THE OCEAN



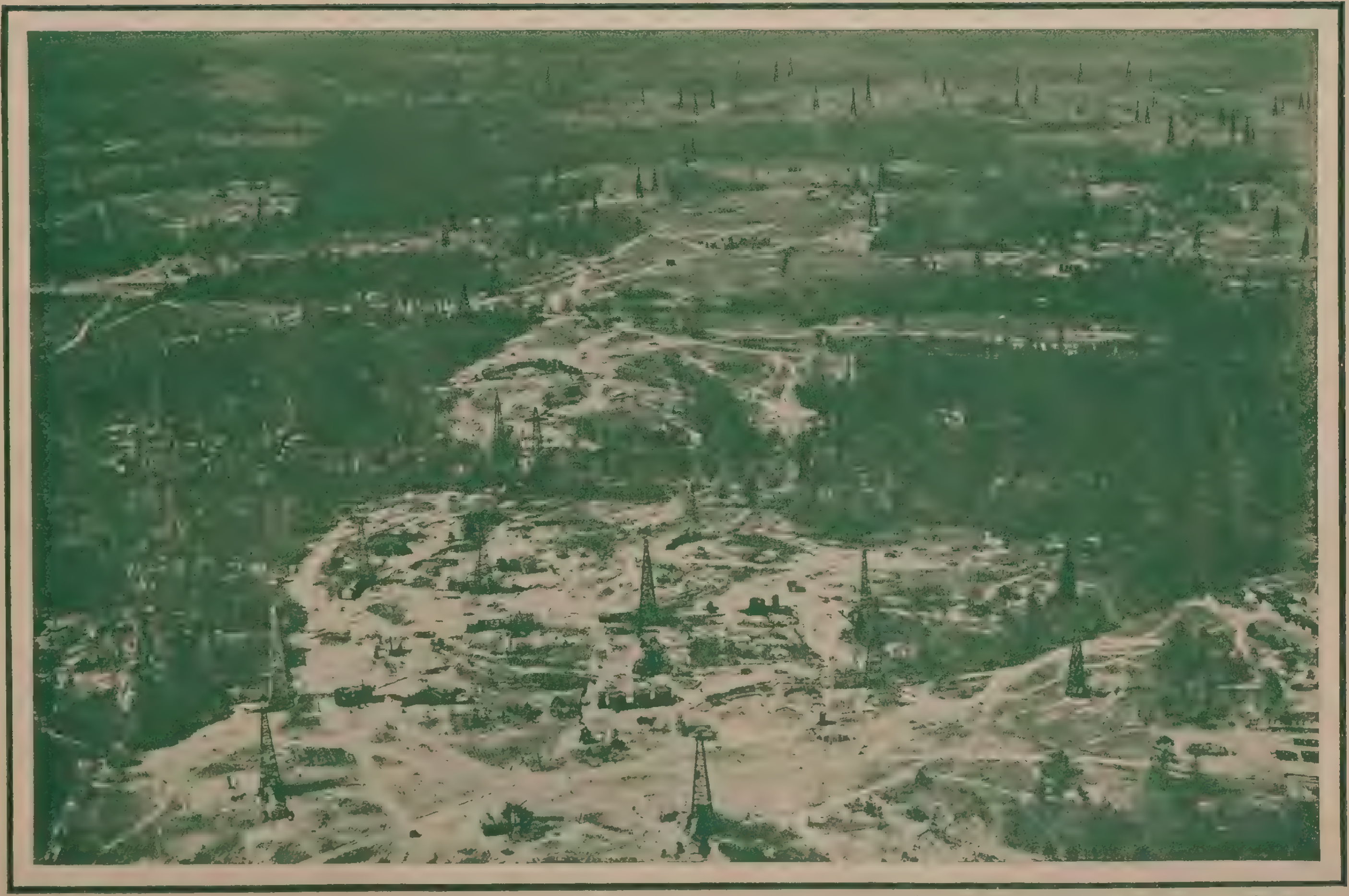
Courtesy, California Oil World

TOP, LEFT: A BURNING "GASSER." A GASSER IS AN OIL WELL CARRYING GAS IN ITS UPPER STRATA. TOP, RIGHT: WILD GUSHER. THIS IS AN OIL WELL NOT YET UNDER CONTROL. BOTTOM: OIL FLOWING WITH TREMENDOUS FORCE INTO A RESERVOIR THROUGH PIPE LEADING FROM AN OIL WELL

THREE GREAT OIL RESERVOIRS. CAPACITY OF ALL COMBINED, 2,250,000 BARRELS

of petroleum, it was little used. One reason was because people did not know how to get it or what to do with it. Early American settlers used sometimes to put blankets on the ground where oil was and let the thick wool absorb the liquid. Then they would wring it out. Others skimmed oil from the top of springs. None of these people, however, got very much, as you may imagine, and it was not used for burning as is our present-day kerosene, but was used instead as a lotion to be applied as a cure for rheumatism.

DRILLING FOR OIL



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AIRPLANE VIEW OF ONE OF THE LARGEST AMERICAN OIL FIELDS

See how many wells you can count, locating them by their shafts

In West Virginia, to be sure, men who were boring for salt in 1806 found petroleum, and in 1848 a man by the name of Keir even distilled some of it and made an oil which could be burned in a lamp, but it smelled so bad and was so expensive that nobody wanted it. A few wells were sunk, but aside from its use for oiling machinery the new product was not taken up commercially. Still there were possibilities in this rock-oil, or petroleum, as it was called. In 1846, Dr. Abraham Gerser got from coal an oil that he called kerosene, and he formed a company which manufactured it successfully. People bought it. They began to use it. The demand became greater. Dr. Silliman of Yale, who had been employed to experiment both with coal-oil and with petroleum, now reported that petroleum could be distilled into a most satisfactory oil for burning.

DRAKE'S GREAT ADVENTURE

In 1859 Colonel Drake was put in charge of a plan to bore for oil at Oil Creek, Pennsylvania. It seemed a wild scheme. Boring into solid rock was not only difficult but expensive. Workmen drilled patiently, gaining but about three feet a day. No one was sure oil was there anyway. The money for the undertaking was quickly spent and still no oil was found. It began to look as if the entire venture must be abandoned. But Colonel Drake's heart was in his work. He was determined to succeed. He used up his own capital and borrowed more. Then on Saturday, April 28, 1859, the drill ceased to meet resistance and moved in the rock clear and free. The next morning, when one of the workmen visited the works, he found the well nearly full of oil. He could scarcely wait until the next day to attach a pump and force from the earth the two barrels of precious oil. Daily the well continued to yield a constant two barrels.

Then came our Civil War. Money was scarce and people's minds too distracted by the great conflict for them to think of anything else. Oil wells seemed of little importance at such a crisis. But no sooner was peace declared than their attention returned to the getting of oil.

With a rush the land about Oil Creek was bought up. Towns sprang into being. Many a person who risked all his fortune in the oil country became rich. It was a stampede such as the Forty-niners made when gold was discovered in California and Alaska. Men sank oil wells everywhere. Now Colonel Drake's well, as it happened, was not a large one, and its yield soon became smaller. So certain had the Colonel been that it would be lasting that amid all the excitement he had not bought up other land, and so when his well began to fail, his fortune was lost and he became very poor.

There were in America, however, many men who had become rich through Drake's discovery and they were far too generous to stand by and see the man to whom they owed all their prosperity suffer. Among themselves they raised for him a sufficient sum of money to make him comfortable, and to this the legislature of Pennsylvania added a pension of $1,500 a year so long as either the Colonel or his wife should live.

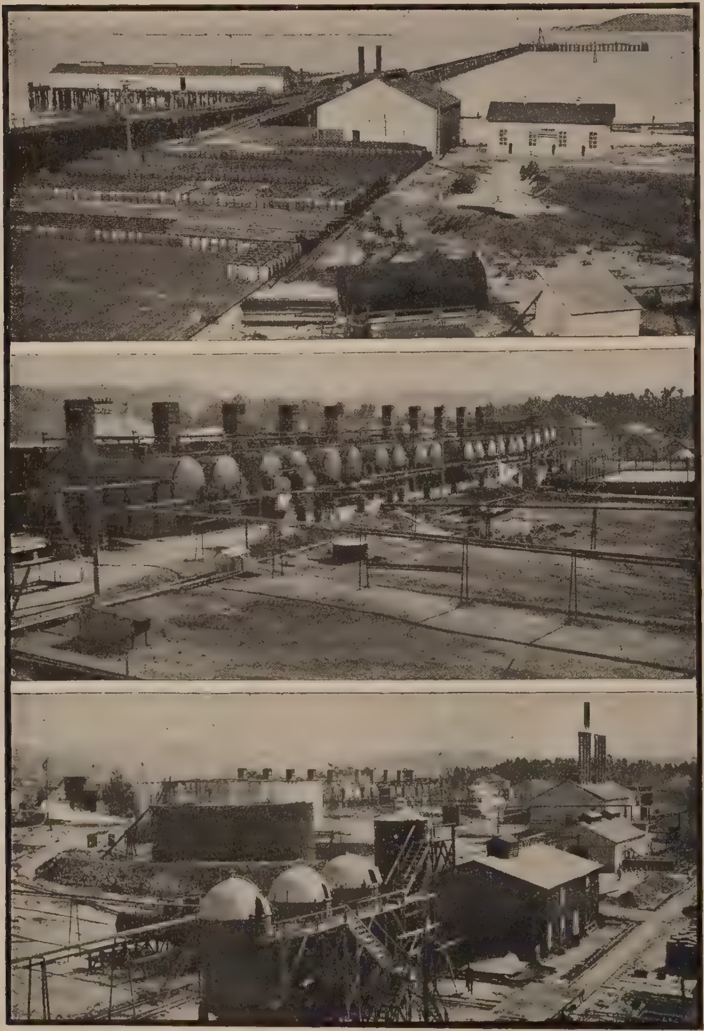
EARLY STRUGGLES IN THE OIL COUNTRY

In the meantime the excitement of searching for oil continued. New country hitherto unsettled and considered valueless was opened up. Men tested for oil, bought land on the chance of making their fortunes, and put their every cent into boring into the rock. Some of these men were successful, and their oil works became centers for towns that either lived until the oil supply was exhausted or grew into prosperous cities; other prospectors were unlucky, and the money put into drilling into the rocky land was indeed sunk in the earth. No oil was found and the once hopeful fortune-hunters faced poverty and despair.

In New York, Indiana, Kansas, California, and Texas, as well as in Pennsylvania, much oil was found, although its quality varied greatly. That which was thick like molasses was used for lubricating machinery. Other oils were separated into their various parts and used for different purposes.

During all these early days of the manufacture of oil, proper care was not taken in distilling it, and there were, in consequence, many disasters. Sometimes a match thrown carelessly on the oil-soaked ground caused fire;

sometimes the tanks ignited, or were struck by lightning and exploded. Yet all the time on went the march of progress. Manufacturers labored to lessen accidents and to perfect methods. Often the wells were clogged by paraffin, and it was at last discovered that by using nitroglycerine, a powerful explosive, they could be cleared and made to yield a far greater supply. Even to-day this method of freeing wells is followed. The explosive is let down, and a cap of powder put on top of it; then a heavy weight is dropped, and with a bang the deep-lying rock is blown to pieces and the oil passage left open.



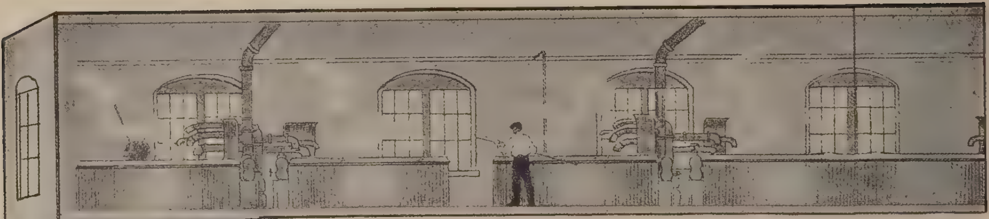
SCENES AT OLEUM, CALIFORNIA, A GREAT OIL CENTER, SHOWING WHARF, CRUDE STILLS AND (AT BOTTOM) KEROSENE AGITATORS

THE PUZZLE OF TRANSPORTING OIL

The greatest problem encountered, however, in manufacturing oil was the expense in transporting the product to centers from which it could readily be sold. Cans and vast tank cars carried the oil miles across the country, to be sure, but as the oil region was rough and difficult to reach, and the distances very great, the profits of manufacture were mostly eaten up by bills for shipping. What was to be done? Here again man's ingenuity came to his aid. Why not run the oil to market in pipes? Why not have miles and miles of pipes reaching from the oil country to the heart of distant cities? It seemed an impossible thing. How was it to be done? The great plan was worked amid the hubbub and opposition of angry transportation companies whose work and consequent profit was now wrested from them. In their rage, men tore up the pipes as fast as they were laid. But in time peace prevailed, and at the present day more than twenty-five thousand miles of pipes carry oil to seaport refineries and to cities near the coast. New York, Philadel-

TOP: GENERAL VIEW OF AN OIL REFINERY. BOTTOM: TANKS FOR BLEACHING REFINED PRODUCTS BY LIGHT

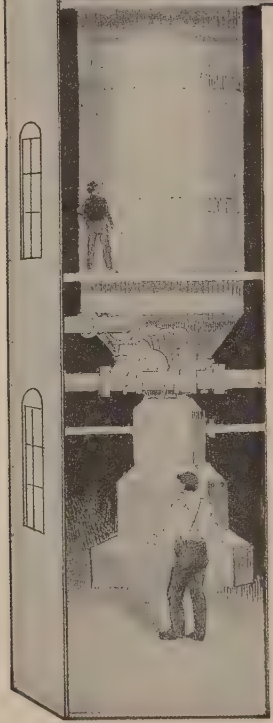
Such bleaching goes back to before the period when sulphuric acid was used.



THE KETTLE HOUSE IN A SOAP FACTORY

The kettles are ranked in parallel rows and reach up through three stories of the building.

phia, Baltimore, Cleveland, Buffalo, and other large centers throughout the country are so supplied. By means of strong pumps the oil is forced on, and when paraffin collects in the pipes and blocks them, as it often does, a tiny machine called a "go-devil" is put inside the pipe and with little revolving knives scrapes away the grease, being propelled by pressure from behind.



WHAT HAPPENS TO CRUDE OIL

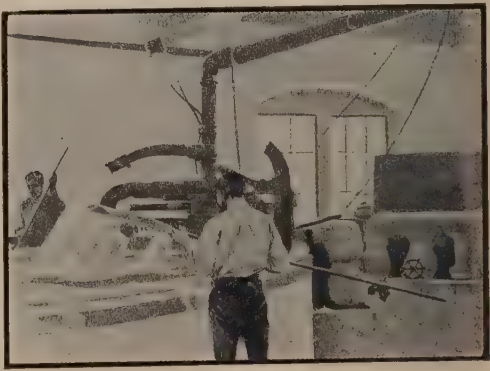
At refineries the first things to pass off in distilling petroleum are the volatile gases, such as naphtha, which are condensed back again into benzine, for cleaning purposes, and gasoline, for motor-cars, trucks, and boats. Then after cooling the still and heating it to a higher temperature, we get kerosene and the burning oils. Lastly come the thick machine oils, vaseline, and the tar products, as well as grease for soap, candles, and salves. Lamp black and chewing gum are also made from petroleum.

The oil which is not wanted for immediate use is stored in giant steel or iron tanks until required for shipping. It is then placed either in tank cars or in tank steamers and carried to various ports. In the meantime the natural gases which flood the oil wells are utilized for lighting and heating residences in towns near the oil country.

A wonderful story — this tale of petroleum.

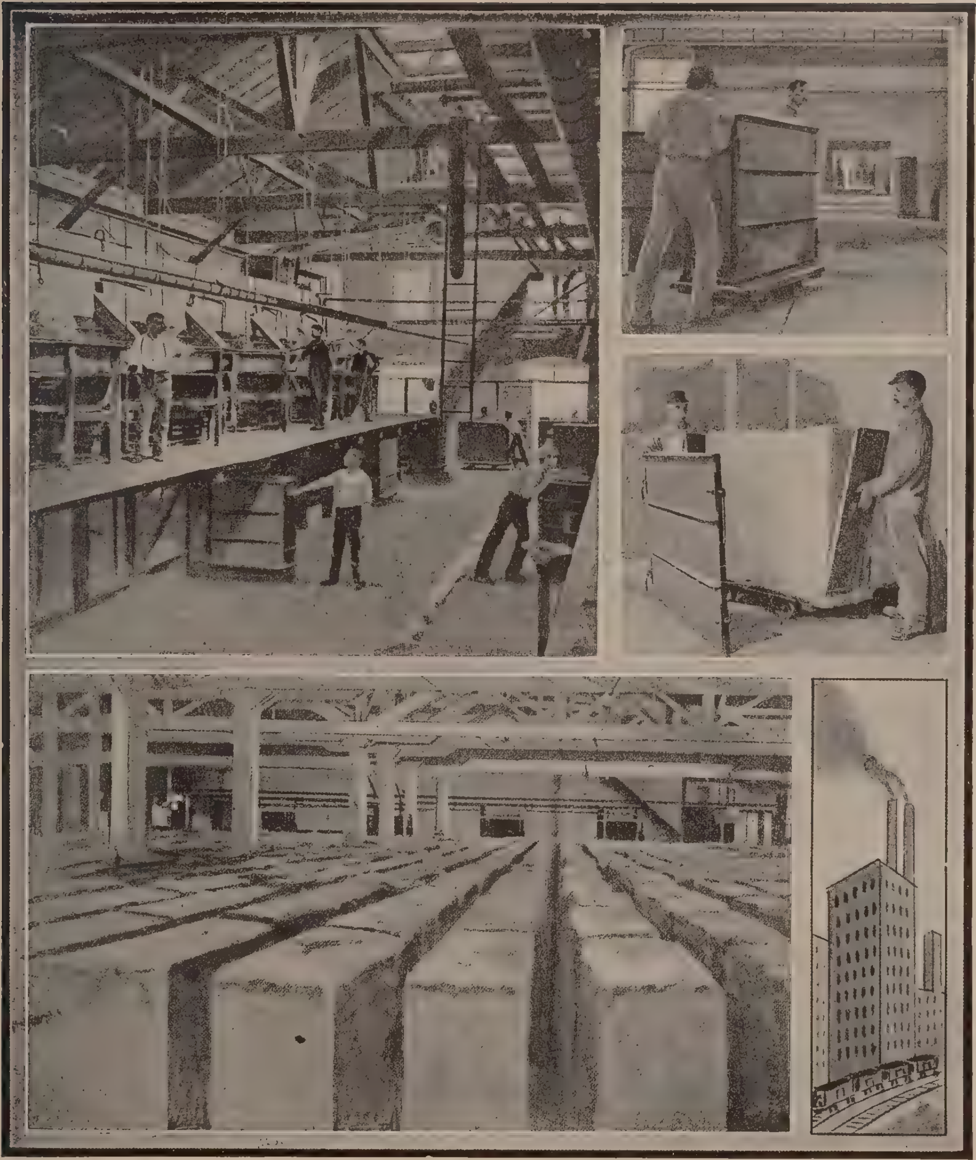
SOAP

SOAP is a mixture of fat and an alkali, usually soda for hard soaps and potash for soft. In making it, however, great care must be taken not to put into it too great a proportion of either of these ingredients. The dirt which we wish to wash from clothing and other things is a blend of oil and dust. Oil from the skin catches dust from the world about us, and in consequence we have a greasy dirt which it is necessary to dissolve before it can be washed



VIEW IN KETTLE HOUSE

Into the kettles are pumped tens of thousands of pounds of "stock" — lye and water. This is stirred and boiled, after which salt is put in to purify it.



SCENES IN A MODERN SOAP FACTORY

In the "crutcher house," shown in the picture at the top, the fibrous, stringy mass of soap, purified by the salt, is made smooth by a process called "crutching," and then poured into frames, which are wheeled into the storage room. Here the soap, after being allowed to cool and harden, is "stripped"; that is, the detachable sides of the frames are removed, and the stripped masses of soap are left awhile to age, as seen in the picture at the bottom. The soap is then ready for the final process of being cut by machines, first into slabs, then into strips, and lastly into cakes.

Photos are here reproduced by courtesy of Procter & Gamble.

out with water. You can easily see, therefore, that if soap has too much fat in it, it simply adds to the amount of oil already in the object we wish to cleanse, and does not break it up into particles so it can be washed out. It is the potash in soap which separates the grease. If, on the other hand, there is too much potash, the penetrating factors in its composition eat into delicate fabrics and rot them, leaving a network of tiny holes in the cloth. So the two parts of soap must be carefully proportioned and just the right amount of each put in.

Toilet soaps have more fat left in them because it would not be good for our skin to have all the oil taken from it; it would then become dry and rough, and would chap in cold weather. Frequently we find that a particular soap has precisely this effect, and we must either supply the lack in oil by making use of cold cream or we must get a different sort of soap.

In making soap the fats are first melted and very carefully cleansed by frequent straining or skimming. Then they are mixed with sodium and potassium. If soap is to be scented, the perfume is put in while the solution is in a liquid state; any coloring matter, glycerin, or other substance, is also put in at this time. The better and purer the quality of the fats from which the soap is made the finer and whiter will be the cakes when finished. The cruder fats are kept for making common soaps. Some of the best toilet soaps are made in France and have in them many costly perfumes and other ingredients. These delicately scented cakes with their peculiarly soft lather are very expensive. The more faint the perfume the more expensive the soap usually is.

After the liquid soap has been thoroughly mixed, scented, or colored, it is poured into molds to harden. It is then cut into cakes and stamped with the imprint of the manufacturer. The various steps in the process of soap manufacture differ somewhat with different soaps. The pictures will show how a well-known brand of soap is made.

CANDLES

CANDLES are the simplest as well as the cheapest method of lighting. Long ago, however, they were far more expensive than they are now, and were considered a great luxury. Very rich persons burned candles of wax and could afford to have their houses brightly lighted at night, but most people were forced to content themselves with the dim flicker of a single tallow dip made at home in a tin mold. Others there were who, like the boy Lincoln, read by the blaze of a burning log. None of these lights were any too satisfactory. The flame from even the best of candles wavered this way and that, often requiring much snuffing or clipping of the wick; to prevent this some people set their candles in a deep sort of shade of glass that they might not sputter or be blown out.

These old-time candles were made by dipping a wick in wax or tallow many times, and letting each layer harden; or else pouring liquid grease into a tin mold in which a wick had previously been placed. Frequently candles were made from the wax of the bayberry, which grew in abundance near the sea.

HOW CANDLES ARE MADE NOW

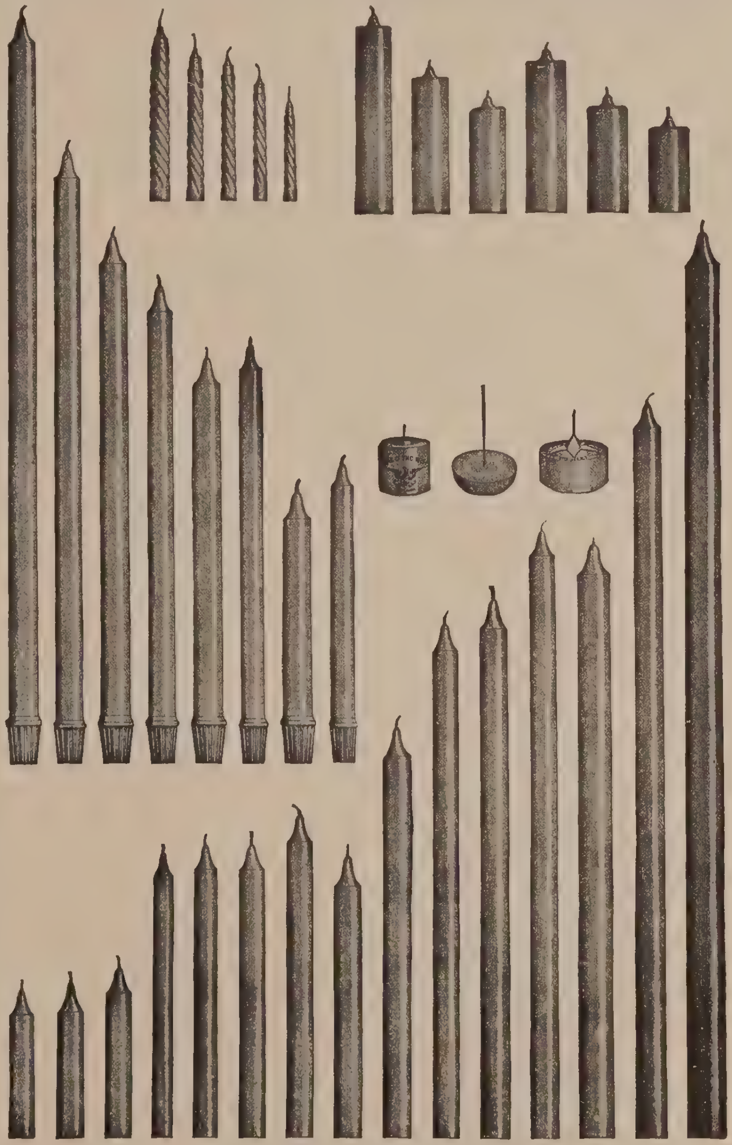
Our present-day candle making, however, is not such a simple process, although the main idea underlying it is practically the same as that used so many years ago. Oils, fats, and tallow, having first been purified, are put into great kettles called "autoclaves" and are mixed together. Next, all glycerin, a fat that would prevent the candle from burning, is extracted by means of lime, water, and a powerful pressure. Then the fatty substances are put into vats, where the lime and other impurities are taken out by means of sulphuric acid. This done, the mixture is ready to be further purified and distilled. It travels through many more tanks before it is sufficiently refined for use. When it is, it drips down long tubes into cooling tins, and is afterward put into strong bags and squeezed in hydraulic presses until all liquid is out of it and nothing but hard white cakes of something which neither smells nor tastes and which looks like wax remains. This hard white substance is called "stearin" and is one of the two things most necessary in making candles of the better grade. The other thing is paraffin, and this, as you already know, comes from refining petroleum.

Into great kettles are tossed the stearir and the paraffin, and there they are melted together by means of steam heat. When thoroughly blended the liquid is ready to be molded. If colored candles are to be made, the coloring matter must be put into this liquid.

There are three ways of making candles, by dipping, by pouring and rolling, and by molding. Tallow candles are made by dipping, whence their name, tallow "dips." These are the cheaper grade.

Again and again the two ends of a long cotton wick are dipped into the hot fat and allowed to cool until coated to the desired size, two candles thus being made at the same time. They are then hung across racks until they harden.

Pouring and rolling is the method used for wax candles, the wicks being fastened to a hook and the wax poured over each in turn. The candles are afterward rolled under pressure and trimmed. All other kinds of candles are made in a candle mold. The machines now most used will mold as many as a hundred at a time, and some as many as three hundred and sixty. The hot candle-stock is poured into a trough, from which it runs on into the molds already fitted with wicks from a frame stocked with bobbins of wicking. It is cooled by letting in cold water, and then a workman forces the candles from the molds by touching a lever.



STEARIC ACID, OR "STEARIN," CANDLES

Representative shapes and sizes. From Lamborn's "Modern Soaps, Candles and Glycerin."

FLOCK OF SHEEP, EASTERN SLOPE OF THE CASCADE MOUNTAINS, WASCO, OREGON

WHERE DO WE GET WOOL?[1]

HOW many of us realize, when bundled into our warm winter woolens, the varied and interesting journey the wool has traveled before it has reached us? What do we know of the perils of growing wool, or of the great woolen mills where the wool is made into finished cloth?

Wool growing is one of the largest industries of America. The states engaged in this industry in order of the quantity of sheep they foster are: Montana, Wyoming, New Mexico, Idaho, Ohio, California, Texas, Colorado, Michigan, Pennsylvania, Nevada, Washington.

Free grass on the western ranges as well as the healthiness of the flocks are the factors which have led to sheep-raising in certain localities. New Mexico is the oldest center for "sheeping." Here great herds dot the high plateaus, and are fed on the rich grass thriving there. The sheep-owners make corrals of cedar into which they drive their flocks at night that they may be sheltered from coyotes, or prairie dogs.

In other states sheep are raised on big ranches, kept in vast inclosures, and fed with alfalfa hay, grain, rape, kale, corn, and pumpkins. Colorado often fattens her sheep on Canadian peas, which grow readily in the soil. Still other states turn their flocks free on the ranges and throughout the year trail from low to high ground in search of food.

SHEEPING ON THE RANGES

"Sheeping on the ranges" is a most picturesque industry. As soon as the herds are sheared in April all the sheep in the flock are dipped. This process takes place after the shearing, because at that time the wool is closely cropped and will most easily dry. Some owners dip their sheep twice a year. Dipping prevents "scab" — a disease common to sheep, and one which if allowed to gain headway will infect an entire band, causing the wool to peel off in great patches. Dipping also prevents ticks and diseases of the eyes.

HOW SHEEP ARE DIPPED

A long, narrow trough just wide enough so the sheep cannot turn is used for dipping This trough is often made of cement or concrete, and has an incline at one end down which the sheep are hurried. At the other end of the trough is a draining platform. Various solutions are used for the dip — mixtures of coal-tar, sulphur, or lime; but whatever the solution, it must be hot to be of value. The sheep are walked down the incline and then, plunging into the trough, they swim their way to the other

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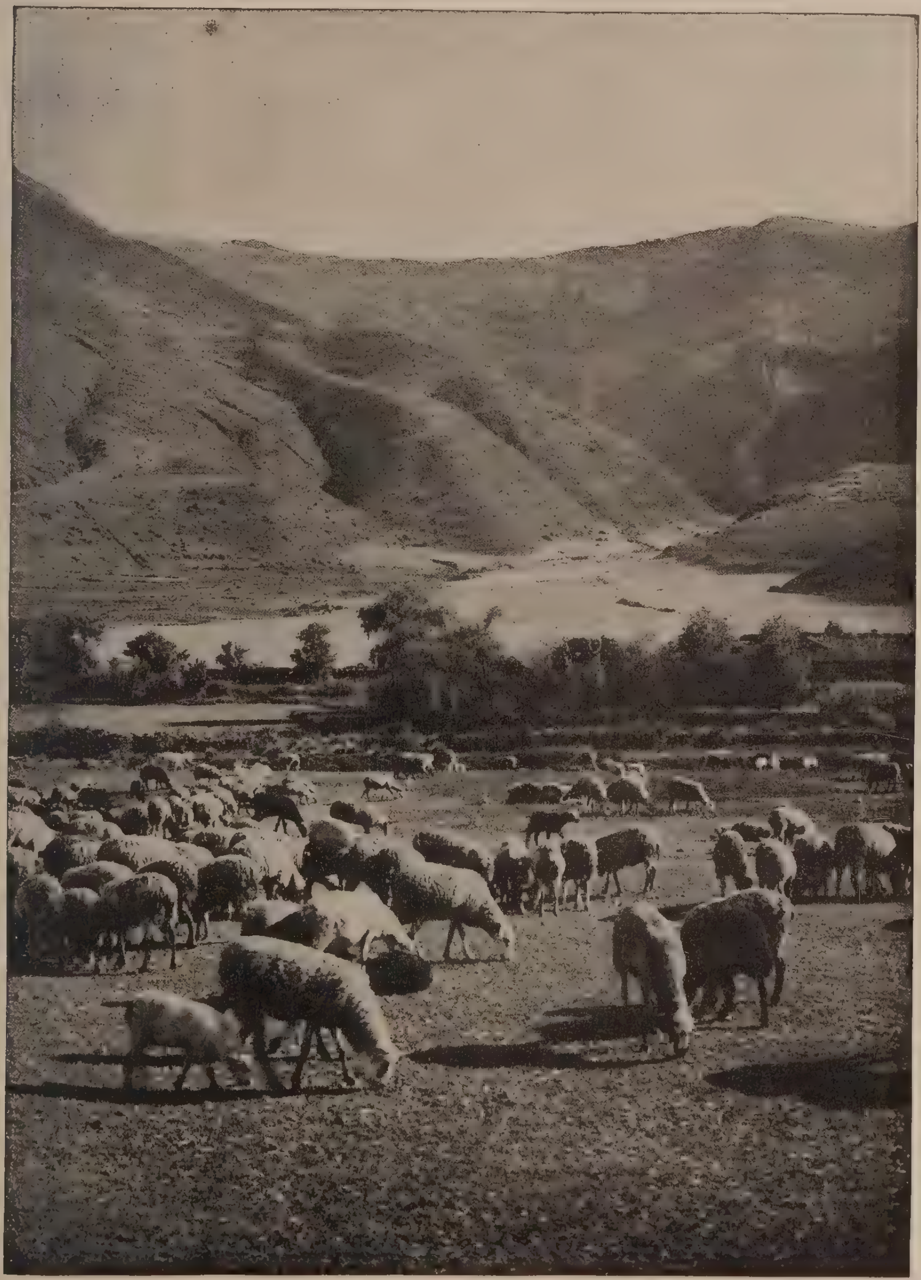
[1] The material for this article is taken from "The Story of Wool," by Sara Ware Bassett, and is republished through the courtesy of the Penn Publishing Company of Philadelphia.



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SHEEP-RAISING IN A SUNNY VALLEY AMONG THE ANDES NEAR CUZCO, PERU (FARM BUILDING AT RIGHT) end. Midway stands a shepherd with a staff in hand, and with it he pushes the heads of the sheep under water at least twice as they pass him. This cleanses the heads and eyes of the herd as well as their bodies. If new flocks have been purchased they are kept in a pen by themselves until they are dipped in order to make sure that they are clean and will spread no parasites through the flock.

MAKING UP THE FLOCKS

After the sheep have been dipped they are separated into herds. Each herd must have some "flock-wise" sheep in it to act as leaders for the others. These leaders are often old ewes that have long been in the flocks, or sometimes wethers. A few goats are often of service, as they are able to find food and water without the aid of the herder. Sheep cannot do this. They are the most helpless of creatures. They can find no food or water unless led to it, and if they are separated from the flock they are unable to find their way back. If they had not a strong instinct to keep in a herd and follow their leaders blindly, they would have a sorry life. Therefore, in herding sheep, it is always necessary to have a few wise ones, capable of understanding to some extent the wish of the shepherd. Yet despite the higher intelligence of these leaders, even they will sometimes become panic-stricken and communicate an unreasoning and disastrous impulse to the entire flock. These impulses are called the "flock mind"; frequently it is the cause of herds of sheep doing most unexpected things. Leaders will become frightened and turn back on the flock, at which all the sheep will turn on each other, pile up, and many will be smothered or trampled to death. It is one duty of the shepherd to try and direct the "flock mind" so that no harm will come to the fold.

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DIPPING SHEEP, NEWMARKET, NEAR MELBOURNE, AUSTRALIA

In addition to the leaders every flock must have markers to aid the shepherd in keeping track of his sheep. All sheep will gradually work themselves into a particular order, and will jealously guard their especial position in the flock.

This is a great help to the shepherd, for it enables him to place a black-faced or crumpled-horned sheep between every hundred; if one of these markers is missing the shepherd calculates that a hundred of his sheep are missing, for sheep seldom divide themselves from the flock unless a whole group wander away.

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WASHING AND DRYING WOOL FROM THE ANDEAN TABLELANDS

MARKING SHEEP

Every ranch owner has a private mark for his sheep that they may easily be identified if they stray or are stolen. Some owners make slits or notches in the ears of their sheep; while others insert a brass clip in the ear of each animal with an anchor or especial device on it.

READY FOR THE RANGE

After the herd has been dipped, counted into flocks, marked, and the bells have been put on, it is ready for the range. Occasionally these ranges are far away, and the herds, shepherds, and dogs must be transported by train; generally, however, the herder sets out at the head of his flock and with the help of his dogs leads them to the mountain plateaus where grass grows in abundance. Sheep can travel about seven miles a day. The eye of the shepherd is constantly on the alert for rich feed and for water holes. It is his aim to get the sheep to luxuriant cool pastures in the hills before the lambs are born in May and June. There are from two to three thousand sheep in these trailing bands, but at lambing time these are divided into smaller groups.

FEEDING ON THE RANGES

It is customary for range sheep to feed on a winter or lower range, and when the snows are melted go up on a higher summer range where it is cooler and where grass is more plenty. Flocks thus raised become very hardy; they climb and run, have pure air and the cool climate necessary to animals protected by thick, warm coats. If, however, undipped sheep pasture on the ranges, they do much damage by infecting the herbage and polluting the water so that other flocks cannot follow without being similarly diseased.

DESTRUCTION DONE THE RANGES

Great havoc, too, is worked on the ranges by careless or unintelligent herders turning too many sheep into the pastures. This is called "over-grazing." Sheep possess two destructive characteristics — their sharp hoofs, which cut the soil and grind it to powder, and their pointed jaws, with such an arrangement of teeth that they can crop the ground very closely. If, therefore, too many sheep are turned into a given area they will not only crop the growth on the surface of the ground, but they will also dig up the roots and leave the spot barren and the soil powdered to dust. Often it is years and years before anything will grow there again.

HOW OUR GOVERNMENT PREVENTS THIS

To prevent this wholesale destruction of the public lands our government issues to "homesteaders" and to stock growers "permittees" allowing a restricted number of sheep or cattle to pasture within a given area. Thus there is plenty of grass for each sheep and the herd is not obliged to crop the roots of the herbage, or destroy the young shoots in the Forest Reservations. "Rangers" in the employ of the government patrol the boundaries of the Reserves to see that no flocks pass in without permittees. At first the government intended to shut out all stock from the National Forest ranges, but as our western states were dependent upon the sheep and cattle industries this plan seemed unfair. So in order to promote the prosperity of the West, not only were grazing privileges granted, but the Department of Agriculture set itself the task of posting notices where herbage was poisonous; of taking an inventory of the water holes; and of decreasing the vast numbers of coyotes which are one of the greatest menaces to sheeping on the ranges. This kindness, which tended to better conditions for the ranchmen, was met at first by scant gratitude. Shortsighted herders, resenting government interference, tried in every way to outwit the rangers, and there was many a feud between herder and ranger. Still the government worked on. It regulated at what seasons areas might be grazed without danger to the growth and made clear that if grass was cropped in the spring before the roots were established it would die; it also showed the shepherds that if herbage was nipped off in the fall before the seeds had ripened they would not scatter and there would be no supply of fodder the next year. Herds were restricted, moreover, from moving through the Forest Reserves at seasons when the young growth of the trees might be injured.

ENMITY BETWEEN SHEEP-MEN AND CATTLE-MEN

There was yet another evil which the government sought to remedy, and that was the strife between the sheep-men and the cattle-men. Each had his grievance. Since the sheep could crop closer they destroyed the range pastures far more than did the cattle. Then, too, because the sheep had an oily secretion between their toes which kept the hoofs from drying and cracking, a peculiar odor lingered about pastures where sheep had grazed and cattle would not graze there. The sheep-men, on the other hand, declared that owing to the love for standing in marshes and pools cattle polluted the water holes. By allotting a special grazing domain to each party the government has done much to allay this warfare.

ADVANTAGES OF THESE LAWS TO THE GOVERNMENT

At the same time the fees for permittees greatly increase the treasury of our government. The herds enrich the soil, contribute to man's need for food and clothing, and by devouring the light growth on the forest floors decrease the dangers from forest fires. There are 160,000,000 acres of National Forests, and in 1905, 692,000 cattle and horses and 1,514,000 sheep and goats were grazed by 9,781 permittees. In 1910 there were over 35,000,000 sheep in the Rocky Mountain and Pacific coast states, and of these something over 7,500,000 were grazed on the National Forest range.

LIFE ON THE RANGE

When the flock reaches the range the herder finds a spot where there is plenty of grass and a water hole and here he establishes his camp, allowing his sheep to graze freely during the day and bedding them down around him at night. The herder himself seldom sleeps during

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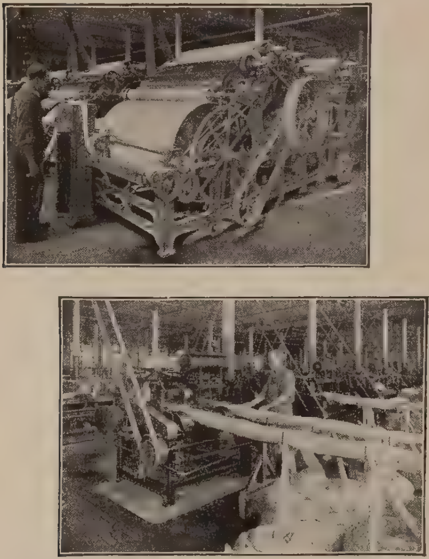
TOP: SHEARING SHEEP BY THE OLD METHOD, AND HOW A SHEEP IS SHORN IN FIVE MINUTES BY ELECTRICAL MACHINERY, IN AUSTRALIA. BOTTOM: INDIAN WOMEN AND CHILDREN SORTING WOOL FOR TWENTY CENTS A DAY, AREQUIPA, PERU, AND ASSORTING AND PRESSING ROOM IN AUSTRALIAN SHEEP SHEDS the darkness. He is watching his flock. In the daytime he can put the herd in care of the dogs, and can then take his rest or can even journey to a central camp and bring back his provisions if this camp is not too distant. If it is, food is brought him three times a week by a camp-tender who rides hither on horseback accompanied by a pack-horse. A good shepherd will always sleep with "one eye open," however. He must ever be on the alert for the unexpected. His flock may be attacked by coyotes; they may become startled and run. It is a well-known fact that when sheep are frightened they make no outcry, they simply run — often blindly following their leaders over the face of cliffs, or wildly stampeding after them if not headed off. Sometimes, too, when the moon is bright they will start off to graze and will wander far away if the shepherd is not watching. For all these emergencies the herder must be prepared. So long as fodder is abundant the herder will remain at this camp, frequently holding it for ten days or two weeks; then, when the crop of grass is exhausted, he will travel on his way up the range.



WORSTED CARDING, AND GILLING AFTER CARDING

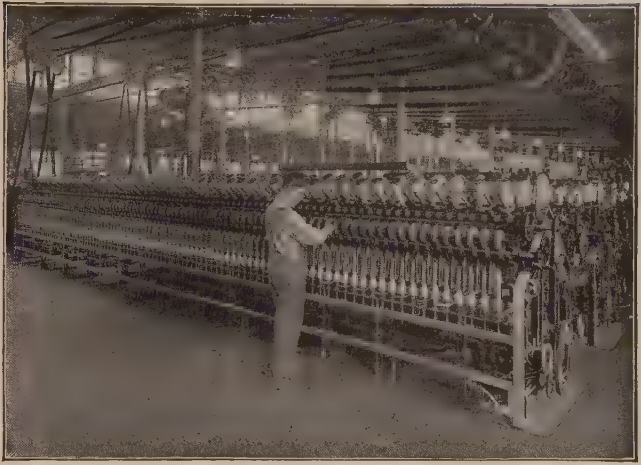
LAMBING ON THE RANGE

Range lambs are born in March, April, May, or June — the time differing in different localities. During these busy few weeks the flock is subdivided into smaller groups and more shepherds are sent to aid in caring for the herd. It is at this season that the flock is most at the mercy of coyotes and bobcats, and to protect the young lambs the government has, on many of the ranges, fenced in large areas, transforming them into coyote-proof inclosures. Here portable lambing tents are set up for the ewes. It is an interesting fact that the ewe recognizes her lamb only by the sense of smell; it is possible, if one lamb dies, to fasten upon another the skin of the dead lamb and the ewe will foster it as if it were her own. Young lambs have little body and very long legs. They grow strong quickly and are often able to journey on with the herd in three or four weeks. While they are still young it is well for the shepherd to patrol the flock at night or build fires about it to drive off not only the coyotes but bobcats, bears, and cougars.

FINISHING BOX—ENGLISH DRAWING

GILLING—ENGLISH DRAWING

The pictures on pages 342, 343, 344 are reproduced by courtesy of the American Woolen Co.



ENGLISH CAP SPINNING

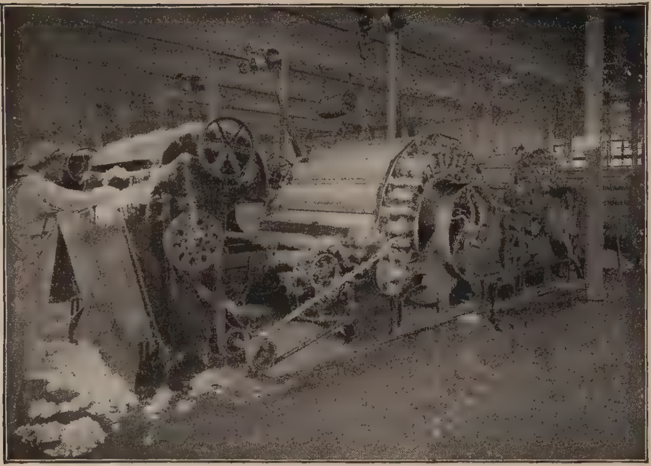
PERILS OF RANGE LIFE TO THE SHEPHERD

It would seem at first glance as if this life in the open must be a most peaceful and healthful one for the shepherd. It is, on the contrary, a perilous occupation and fatal to many engaged in it. The isolation on the range is so complete that often months and months pass without the shepherd interchanging a word with one of his own kind. The men are steeped in silence. In time some of them become unable to express themselves at all; it is not an infrequent thing for them to become insane, not alone from the silence and lack of human companionship, but from watching the continual moving of the sheep. Sheep weave in and out, undulating like a mighty sea, until this peculiar motion affects the reason of one forced to watch them constantly. To obviate this danger the state of Wyoming has enacted a law providing that shepherds shall journey in pairs, and that each shepherd must be supplied with a small, compact library. If a herder's gaze is focused upon a book it cannot vacantly follow the movements of the herd, and his mind will be in less danger of becoming unhinged. The herder remains on the range until it becomes cold in the fall, and then he works his way back to the home ranch or to shearing headquarters, which are often situated near the stations from which the wool is to be shipped. Woe be to the herder who has allowed his flock to crop too closely on the way up, for when he returns he will find scant grazing for his sheep.

TOP: DRAWING IN WARP THREADS. BOTTOM: WEAVING AND SCOURING CLOTH

SHEARING

About the first of April the flocks are sheared, and this is done either by hand or by machinery. There is little difference in the speed or in the expense of these processes. Perhaps power plants clip the wool a bit more evenly. The fleeces are taken off whole, the small parts are turned in, and the fleece is then bound with glazed cord. If fiber cord is used a fleece is often ruined, for the fibers get into the wool and it is impossible to get them out; later, when the wool is dyed, these fibers take a different color



WOOLEN CARDING

and the product cannot be woven. After the fleeces are tied they are packed in huge sacks and are ready for shipping. Many frauds are practiced on the purchasers by dishonest sellers of wool. Since wool is sold by the pound unscrupulous growers will sometimes fill the fleeces with sand in order to run up the weight. If such a trick is discovered and traced to a grower his future crops are boycotted by wool merchants.

HOW WOOL IS BOUGHT

All large wool brokers send their representatives to the wool-growing country when shearing is over, and these buyers bid against each other for the wool. They offer reasonable prices, and if the highest price is not accepted it is agreed among the buyers that none of them will bid again on that particular consignment of wool for at least two weeks. This rule has been made in order that the buyers may not go to the expense of long trips to ranches offering wool for sale only to have their business advances refused.

VARIETIES OF SHEEP

There are many varieties of sheep. The foundation of most of our western herds is the Merino, which is favored because of its tractable nature and its long, fine, and abundant wool. There are Delaine Merinos and Black Tops, both of which are bred from the original Spanish Merino. Then there are French Merinos or Rambouillets. Besides these there are many English breeds of sheep: Leicesters, much raised in Canada and found on some of our western ranches; Cotswolds, which abound in Canada, Utah, and Oregon; Lincolns, the heaviest breed of sheep there is, with very long wool; and the Dorset Horns, which is one of the most ancient of breeds.

The English and Scotch hill regions furnish a supply of Cheviots, Tunis, and Persians. The English Downs foster on their chalky hills a short-haired variety of sheep valuable chiefly for mutton. These are South Downs, Hampshire Downs, Sussex, Oxfords, Shropshire Downs, and Dorset Horns. In addition to the wool raised in the United States much is

FINISHER WOOLEN CARDING AND WOOLEN MULE SPINNING grown in Australia, England, Canada, South America, and Mexico.

SHEPHERD AND DOG IN MONTANA

OUR COTTON CROP

OF the three great kingdoms, animal, vegetable, and mineral, it is interesting to see how each one in its turn ministers to man's three primary needs for food, clothing, and shelter. Wool, man obtains by shearing the sheep's close, fine coat; for silk he depends on the careful spinning of the silkworm; but the cotton for his cloth he can grow in his fields even as he raises his wheat and corn crops for food. While cotton is grown in other parts of the world, we like to think of it as a characteristic American product. We grow in a year about three fifths of the world's total crop. A large part of this we manufacture for our own and foreign use; the rest we export in its raw state. "Cotton," says a leading economist, "has been an outstanding factor in our national history and development; it has exerted a strong influence upon our political, industrial, and commercial life; it has had a most important bearing upon the labor question; it has affected our diplomatic relations with other countries; and it has been for decades the dominant source of our purchasing power abroad."

HOW COTTON GROWS — AND WHERE

If you have never had the good fortune to see a cotton field when the seed pods were bursting, your best picture of raw cotton will probably come from the cotton batting which you have seen in stores or in your own home. Cotton is a soft fibrous substance made up of the twisted hairs which clothe or cover the seed pods of the cotton plant. The part which we make into cloth is the soft wrapping of cellulose or plant stuff in which Nature wraps the precious seeds of the plant for protection until they are grown. Within the seed pod, or "cotton boll," as it is called, lies this soft mass made up of hundreds and thousands of tiny fibers which are from one to two or two and one half inches long. Because they have been wound so tightly about the seed, they have a natural twist which persists after they have been put together into one long thread, and which makes one of the useful qualities of spun cotton.

If we were to stretch a "cotton belt" across the United States, as we pictured ourselves placing a "wheat belt" around the globe, the cotton belt would fall farther south. Cotton is a native of the tropics, of South America, Africa, Southern Asia, and the West Indies. The most valuable cotton in the world, noted for its length and silkiness, is called "Sea Island cotton," because it was first grown on islands off South Carolina and Georgia. Cotton was grown in Egypt as early as 325 B.C., and has been used in India for uncounted centuries. Early explorers found the Indians raising cotton in New Mexico. Its range is about forty degrees north and south of the equator, though it grows best within thirty to thirty-five degrees either way. It flourishes in a warm, humid climate with plenty of rainfall and abundant sunshine. The conditions in our own Southern states are very favorable, our cotton belt including all the states from North Carolina through Texas, while the rest of the world's crop is raised chiefly in Egypt, India, South America, Russia, and China.

Cotton in our own country is usually cultivated as an annual, being raised from seed. The plants grow to the height of a low shrub. "Throughout all the cotton belt," writes Fisher,

COTTON SPINNING IN EGYPT; COTTON PICKERS; COTTON BOLLS; BALES READY FOR SHIPMENT

"the seeds of the cotton are planted in the spring. During the growing season the stocky bushes are rich green with maplelike leaves. By midsummer time the fields are gardens of hollyhock-like blossoms, pink and white. Soon these fall, leaving little green seed-bearing bolls, which, when ripe, burst open and show the fluffy white cotton fiber ready for the picking." A field of cotton is a beautiful sight.

Beneath the beauty the planter is watching constantly for the enemies which lie in wait to ruin his crop. The plants must be carefully watched, tended, and cultivated, for they are threatened by diseases which may visit them, by worms which may attack them, and most serious of all by insect enemies, notably the boll weevil. This insect, which came into this country from Mexico in 1892, has worked its way northward and eastward throughout the greater part of our cotton regions. The weevil punctures the cotton boll and lays its egg in it. The larva which develops from the egg destroys the fibers within the boll. The farmers of the South are fighting this pest with every force modern science can command but with only moderate success.

The crop begins to mature in the summer and continues to do so until the late fall, the cotton being gathered, usually by hand, by pickers as fast as the bolls ripen. Growers tell us an average picker will gather from two hundred to two hundred and fifty pounds of cotton in a day. The planting, tending, and picking is a great Southern industry, keeping men, women, and children at work in the fields.

After it is picked the cotton fiber must be separated from the seeds to which it clings so tightly. Here the cotton gin, invented by Eli Whitney (of which the story is told earlier in this volume), serves its useful purpose. When the seeds have been separated from it, the mass of cotton is compressed into bales and shipped to the mills, where it is the raw product of one of our great textile industries, as described in a later chapter. While our cotton crop used to be valued only for the cloth fibers, its seeds are now recognized as a valuable by-product because of their oil and are the basis of still another great industry.

MOTH OF ERI SILKWORM

SILK

HOW strange it is that a material as useful and beautiful as silk should have its origin with anything as ugly as the silkworm! Had it not been for the caprice of the Chinese Empress Yuen-fi we might never have known that the tiny, peanut-shaped house spun by the hungry little worm was good for anything at all. It was centuries ago that the old Empress found out the secret of reeling the silk off the cocoon, and spinning it upon a rough sort of loom that she herself concocted. Since then, each year, when the mulberry leaves open, the Chinese make offerings in their temple within the palace grounds at Pekin to Yuen-fi, the Goddess of Silk. Well may they feel grateful to her! It is to her discovery that China owes much of its prosperity. No sooner was the story of the silkworm told in the kingdom than all classes of people set about raising silkworms as an amusement. High and low caught up the novelty. But the Chinese had no notion to tell their secret to other nations — no, indeed! When Alexander the Great invaded Asia with his army and saw there silken garments worn by the Chinese nobles, he carried back to Greece not only some of the new material but some of the raw silk which he succeeded in having woven on crude looms; but where the Chinese got the silk, he could not find out. No sooner did the Romans, who were always alert for anything new and beautiful, see these silks than they procured some of the raw material and learned from Grecian weavers how to make the exquisite, shimmering cloth. Rich Romans of the Christian era went about in silken togas. Emperor Aurelian, who came to the throne in the third century, refused to wear silk himself or let his wife wear it because he considered it far too costly and magnificent; Justinian, on the contrary, had no such scruples, but encouraged the people of his time to make silk until its weaving

SILKWORMS FEEDING ON MULBERRY LEAVES

LARGER SILKWORM FEEDING ON MULBERRY LEAVES

The pictures on pages 347, 348, 350–352 are reproduced by courtesy of American Silk Journal.

MOTHS BURSTING FROM COCOONS

became one of the industries of the Byzantine empire.

All this time the Greeks and Romans had no idea how the people of China got the raw silk. Where could it come from? Was it a product of plant or tree? Wise men puzzled until their brains were tired and still no answer came to the enigma. Then, the story goes, on one unlucky day a Chinese princess betrayed her country by carrying to India in her headdress some silk-moth eggs and some seeds of the mulberry tree. How delighted the people of India were to learn at last the wonderful secret! They could not keep it to themselves. You know how hard it is to keep a secret. The natives of India must needs whisper the tale to the Persians, and the Persians whispered it to somebody else. Farther and farther spread the story. By the sixth century the Saracens, who overthrew the Greeks, had spread the art of silk-making throughout Europe. Some persons declare that the unfortunate Chinese princess was not responsible for all this and that it was two old monks instead who, dazzled by gold, first carried the silkworm out of China. However that may be, the secret got out and there was nothing the Chinese could do about it. Florence, Milan, Genoa, and Venice were soon manufacturing exquisite silks, and at the close of the fifteenth century France took up the industry, which at first did not thrive there, but which later triumphed over many failures and is now a great source of revenue to the French people.

HOW THE SILKWORM CAME TO AMERICA

It was Flemish weavers fleeing to England in the sixteenth century who carried the industry there, and, since this was about the time of the settling of the Jamestown colony in Virginia, what more natural than that King James I should introduce the culture of silkworms into America? Virginia, however, soon abandoned it for the far more profitable tobacco crop; nor did Louisiana make a success of the venture. Still the king persisted. A royal decree was issued by which in Georgia a settler must plant one hundred mulberry trees on every ten acres of land or forfeit his grant. Still the industry did not prosper. Getting the raw silk off the cocoons was too delicate a task for the great clumsy southern laborers. Besides, the king put a high tax on all weaving machinery. He had no mind to have the colonists manufacture their raw silk themselves. His plan was to take the raw material from them and carry it free of cost to England in order to save the English the expense of buying it from China or Italy. Do you wonder that the American colonists were not especially eager to raise silk under such conditions? After the Revolution a little group of men started raising silkworms in Connecticut, but did not find the scheme profitable. Since that time America has given up attempting silkworm culture. We have no labor so cheap as that in China and Japan, and as raw silk is admitted to our country free of duty we have found that it costs much

MOTH BURSTING FROM COCOON

less to import it from foreign markets than to raise it at home. We do, however, manufacture quantities of silks quite as beautiful as any turned out by the mills of France or Italy.

In Paterson, N. J., are tremendous factories, where some of the finest silks, satins, and ribbons are made. We also specialize in various silk products, some mills making nothing but sewing-silk and twist; others embroidery silks; still others silk fringes. This latter product is made from the short bits which in former times used to be considered worthless and were thrown away. As the silk trade has grown, our factories have steadily improved. We now have in our mills many skilled workmen; we use the most up-to-date type of the wonderful Jacquard loom (see page 359); and we are no longer dependent on foreign designers, since our own art schools send out trained artists whose patterns make a most favorable showing with those of the Old World. These designers have their headquarters in the mills, where they keep in constant touch with the trained chemists who direct the dyeing of material. This is almost a business in itself. The chemist must understand not only what colors to mix to get the shades he desires, but he must also know which dyes fade most easily; which rot the material; what mordant to employ to set the color; and what bath of chemicals will give the silk more weight or body. There is very little pure silk in the market. In China the Mandarin coats, kimonos, and obis made from pure silk are instantly bought up by the Chinese people and seldom reach the outside world. Most other silks, both foreign and American, are loaded with chemicals which give them a stiff rustle termed "scroop" by the manufacturers and cause them to wear out more quickly. Pure silk has none of this crackling sound. Often the cheapest silks will be the stiffest and the "noisiest." It is to be hoped that in time all silk mills will not only give us cheaper and better silk but will do away entirely with "loaded" or false silk.

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SORTING COCOONS, ANTIOCH, SYRIA

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CHILD LABOR IN TURKISH SILK CULTIVATION

THE SILKWORM AND HOW HE LIVES

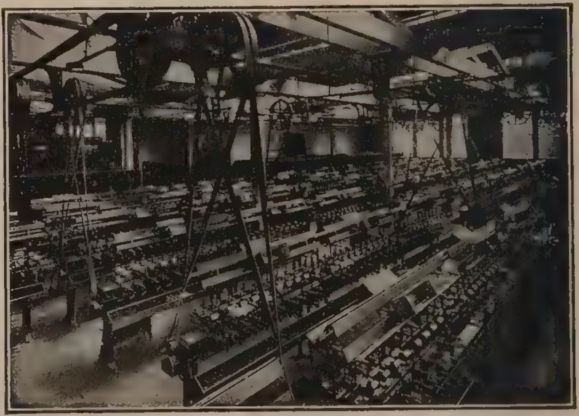
To anyone unaccustomed to raising silkworms the creatures present a most repulsive

JAPANESE GIRLS SEPARATING SILKWORM EGGS FOR HATCHING

appearance; nor is their culture an easy task. They are very delicate, quick to suffer from a change of temperature or from noise, and much annoyed by odors of any sort. Those caring for silkworms are not allowed to use even the most faintly perfumed soaps or colognes. Furthermore the worms will eat but one variety of food, and this must be carefully prepared. If, in addition, the rooms where they are kept are not absolutely clean they often become infected and die. So, you see, many are the trials of the silkworm grower! Only as the result of myriads of disasters does he now meet with his present success.

In the first place the mulberry trees, which grow almost as fast as the worms themselves, must be planted from seed. In three years they mature. Like tea bushes, they must be clipped at the top to keep them low so that their leaves will be well within the reach of women and children whose duty it is to pick them. All fruit must be also nipped off before it starts to mature, that no strength may be taken from the leaves. As the mulberry tree is not one which is in leaf all the year round, the season for raising worms can only last while the leaves last. In consequence the eggs, which are about the size of a pinhead, are kept on sheets of paper and hung in a cold place until the trees begin to bud and there is a prospect of food for the little creatures. All eggs which are to be hatched are first carefully examined with a microscope and those that are diseased are destroyed. The perfect eggs are then placed in incubators to be hatched; if the weather is mild, however, incubators are not necessary. How like a hospital ward is this room in which the young worms are grown! Walls, floors, ceilings, shelves — all are washed and spotless. Since smoke does not harm the worms, the rooms are thoroughly fumigated to banish lurking germs.

In addition there must be good ventilation, for any creature growing as fast as the silkworm needs an abundance of fresh air. The leaves fed to the young worms must be of the tenderest quality, warmed to the temperature of the room, and broken in small pieces. Full-grown worms, on the contrary, must be fed on old tough leaves, as the tender leaves do not agree with them. When the leaves



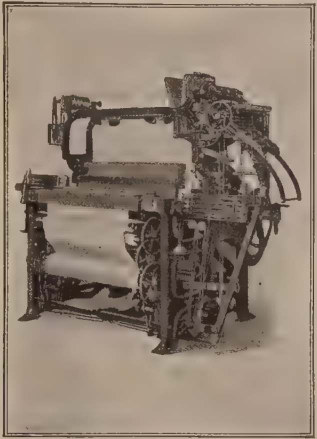
VIEW OF QUILLING DEPARTMENT IN AN AMERICAN MILL are ready they are placed on feeding trays with perforated bottoms in order that all the waste can drop through and be carried away without disturbing the worms.

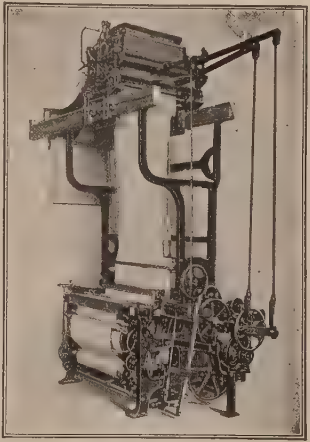
THE LITTLE GLUTTON SILKWORM AND HOW HE OUTGROWS HIS COAT

The tremendous appetite of the silkworm is almost beyond belief. It is said that an ounce of eggs, before maturing, will devour a ton of mulberry leaves. The moment the worm is hatched and reaches the air he swells up many times larger and begins to eat, and day and night — except when he is asleep — he keeps on eating. You might hear, if you were to listen, the crisp cutting of the leaves as he feeds. When about half-grown he is from three to three and one-half inches long, has a head protected by a hard cap, and a pair of large jaws. The glands where the silk is made run the whole length of his body and meet near his mouth in the spinneret, or place where he makes the thread. The silk is like jelly when inside the worm and hardens when it reaches the air. Although there are two glands for making it, it comes from the spinneret a single thread.

OLD-FASHIONED WOODEN SILK HAND LOOM

Of course, the more the silkworm eats with his big jaws, the fatter he gets. One skin after another becomes too tight. He sheds the first at the end of five days, hanging himself up as if asleep, until it cracks off and leaves him with a larger one. From this time on he sheds his skin every five or six days. At last, when he has lived about four weeks, he seems to have eaten all he can and he then raises his head and begins to twist and turn uneasily. The men who are taking care of him know what that means. He is looking for a place to build his house. Gently he is lifted to a shelf covered with dried brush and, after selecting a place he likes, he goes promptly to work spinning his cocoon. While he spins there is a soft sound as if rain were falling, and when the attendants listen and hear no more sound they know that the small golden-yellow house which it has taken about three days and nights to make is done.

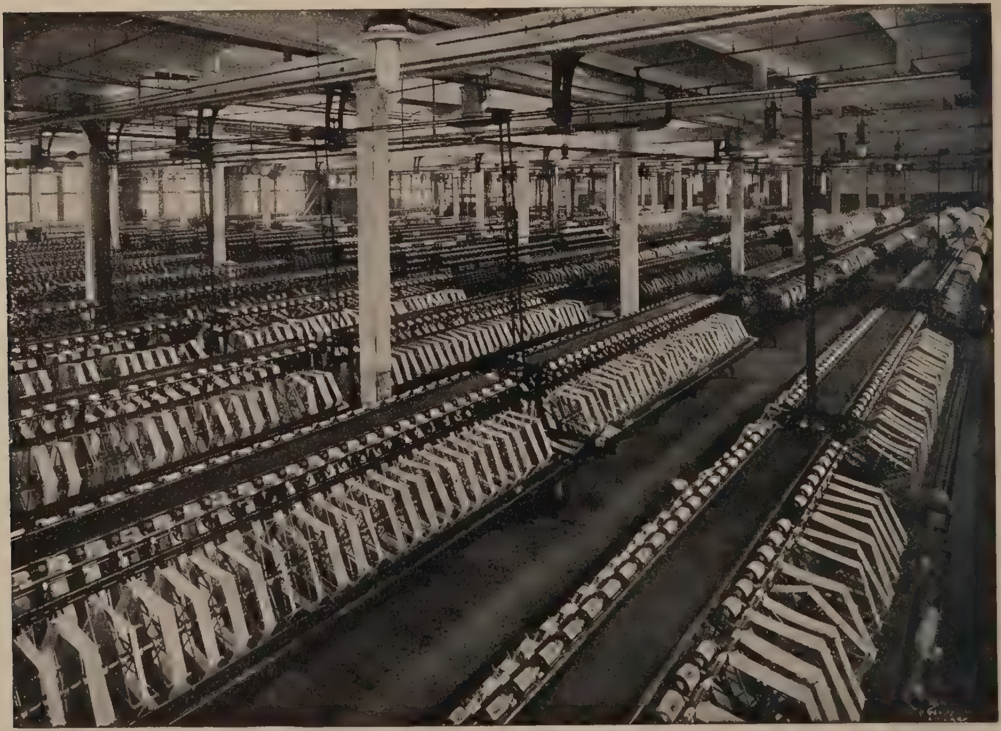

MODERN LOOM


JACQUARD LOOM

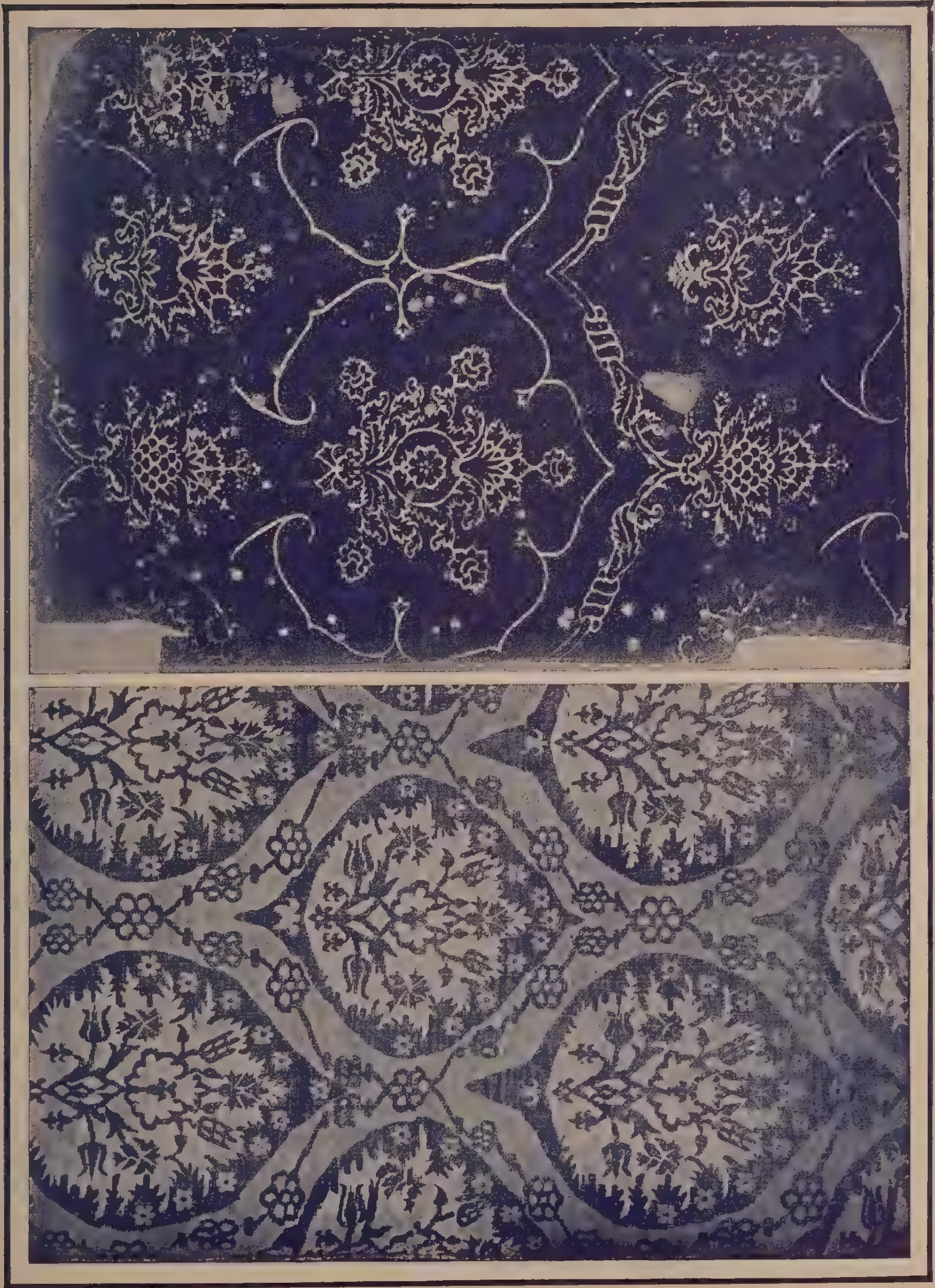
WHAT HAPPENS AFTER THE HOUSE IS MADE

Now if left to himself the worm would sleep inside this house about a month and then, making a hole through one end of it, come out a moth. In doing this he would sever all the silken threads covering his cocoon so that they would be of no further use. If the grower is intending to let the moth come out and lay eggs for other silkworms, he does not interfere, but allows it to mature and come forth; it is then carefully examined with a microscope, and if it is not diseased it is allowed to live. Generally it lives from ten to fifteen days, and in that time lays anywhere from three to seven hundred eggs. It does not fly at all. If on the other hand the grower wishes silk and not eggs, he must prevent the moth from coming out and breaking the thread on the outside of his cocoon. This is accomplished by exposing the cocoon to steam or dry heat so that the moth is quickly killed. The cocoon, together with many others, is afterward tossed into a mixture of soap and water which soaks out the stocky substance blended with the silk. Then the reeler, or thrower, as he is called, who must always be a very skillful person, catches the ends of silk from several cocoons with a brush and, joining them together, winds them off on a reel. This is the most delicate part of silk-making. Some of the cocoons prove to be more cottony than silky, and are thrown out as useless. Others have only short fibers that must be carded and spun like cotton. The silk made from these is called spun silk and is of inferior quality. The best fibers are long, and by joining them a continuous thread is made which is ready for spinning without further trouble; the finest silks are made from this long-fibered thread.

Before weaving, all the silk is scoured or cleaned, and in addition, if desired for silk material of delicate shades or for white silk, it must be bleached. Sometimes the thread is dyed before weaving and these vari-colored threads are then woven into a many-hued pattern against a background of plain color; sometimes, as is more often the case, the pattern is printed on the silk after weaving, just as calico and percale are printed. As it takes from two thousand to twenty-five hundred silkworms to produce a pound of silk, you can see how many creatures probably had a share in making your necktie or your hair ribbon.



WINDING ROOM IN AN AMERICAN PLANT



TOP: ITALIAN VELVET, FIFTEENTH CENTURY. BOTTOM: PERSIAN VELVET

Reproduced from rare specimens in the Museum of Fine Arts, Boston.

A SILK FINISH — MERCERIZATION

The luster of silk is so beautiful that attempts have been made for many hundreds of years to obtain this effect with other textiles. John Mercer, a calico printer of England, made the discovery which led to success in this line in the year 1844. One day he was trying to filter a solution of caustic soda through a piece of cotton cloth. It ran through rapidly at first, then more and more slowly until at last it stopped altogether. Investigating for the reason, he found that the cotton fibers swelled until they were almost round under treatment with caustic soda. Working further on the process he discovered that cotton cloth so treated and shrunk was much stronger than in its original form and took on many dyes better. For this process he took out patents in the middle of the nineteenth century, but the strange fact was that he never discovered another effect of treating cotton with this solution, an effect which was to make his name a familiar term in the textile industry. He had allowed the cotton to shrink under the treatment with caustic soda. Fifty years later chemists working with his process discovered that if the cotton was held from shrinking, or stretched before the soda was washed out of it, a silky luster resulted. This is the basis of the modern process of mercerizing cotton to give it a silk finish.

ARTIFICIAL SILK — RAYON

Artificial silk imitates in its production the spinning process of the silkworm of forcing a semiliquid substance through a tiny opening and letting it harden into a fiber. Cloth made from such fibers was first shown at the International Exhibition in Paris in 1889, but has come to successful commercial use only since the War.

The triumph of chemistry and machinery in imitating the method of the silkworm is known to all purchasers of rayon. In comparison with silk, rayon has certain definite properties. It partly loses its strength when wet, but regains this strength when dried. This ability to gain and lose water and to change its character in the process has been one of its most noticeable characteristics. Of this Mr. Luft says: "The power of absorption of moisture is an advantage of rayon when used for underwear, because it absorbs the perspiration from the body and permits the evaporation of the excess moisture, thus keeping the skin dry and comfortable. . . . It has still another advantage in this respect because natural silk rots from perspiration and turns yellow, while artificial silk remains white. Real silk is generally weighted with metallic salts. . . . Artificial silk is never weighted; it is a pure cellulose product." Rayon also takes dyes well, which makes it extremely desirable in modern dress where a rainbow of colors replaces the few shades of a half-century ago.

Altogether, while rayon does not replace silk, it is a valuable modern textile of similar qualities which has already made for itself a place as an indispensable product.

THE HISTORY OF VELVET

THE word *villosus*, from which our word "velvet" is derived, means "shaggy hair," and refers, no doubt, to the furry nap, or pile, which covers one side of the goods. The name was probably given by the Romans, who, when they fought in the East, brought back with them this strange furlike variety of cloth. It was immediately put to use for decorating both Roman temples and palaces and was much admired. The art of making it was unknown in Rome. Probably this velvet brought from the Orient was made on hand looms, as oriental silks were made, the secret of weaving it having originated in India in the dim past.

Even as early as the fourteenth century we hear of velvet being used in the churches of France and Italy. Beautiful robes, embroidered in gold, were worn by dignitaries at cathedral services, and these costly relics formed part of the wealth of the churches. Altar cloths of crimson or black velvet were used as backgrounds for exquisite hand-made laces which covered the altars on state occasions or on festival days.

Later, noblemen of the Middle Ages began to enrich their costumes by adding touches of velvet; they wore velvet caps and cloaks, and many a silken doublet was ornamented with slashings of the same rich material. Ladies of high rank as well as kings and queens used it for court costumes. Since, however, it was so much more expensive than silk, it was until recently a great luxury. Now that modern manufacturers have mastered the art of making it, the cost of producing it has lessened.

WHO MAKES VELVET?

Lyons and Genoa make the most beautiful velvets in the world. Some of them are woven in one solid color of silkiest texture; other varieties have garlands of flowers in many colors, or conventional figures standing out from a background of silk. Designers are constantly employed to draw more and more elaborate and beautiful patterns. This industry of velvet making, so famous in Italy and France, is little known in England. There are, to be sure, a few weavers who work upon hand looms, and it was some of these who made the coronation robes for the English monarchs; but the art has never prospered in England as in other countries. Germany, on the other hand, has extensive velvet factories where not only most of the velvet used in America is made, but also much of the velvet of the world. When Louis XIV drove the Huguenots out of France they carried the trade of silk and velvet weaving with them. Some of the exiles fled to England. Others settled in Germany. It is to these aliens that Germany owes one of her greatest industries. The two German towns of Eberfeld and Krefeld are given over to velvet making, Krefeld alone having one hundred and twenty factories, besides many mills for the dyeing of silk. In order to encourage the art, the German government offers to its people instruction in designing, chemistry, and other difficult branches of the work. As a result many kinds of velvet once purchased in other countries are now woven in Germany.

HOW DOES VELVET GET ITS FUR?

The soft nap or pile of velvet is made by drawing the threads of silk warp over an extra wire, which leaves millions of tiny loops standing erect and close together. That the velvet may be smooth these loops must be perfectly even and packed tightly together. The closer they are the finer will be the velvet. When these little loops are cut we get the smooth nap and satin-like sheen in which the beauty of silk velvet lies. When the loops are not cut we get the uncut velvet used in upholstery. There is also a raised velvet where loops of varied lengths form the pattern.

Besides good silk velvets, American mills are producing many fabrics with a velvet-like surface. Among these are silk velours, woven somewhat like plush; wool velours, a soft woolen fabric with the nap raised to look like dull velvet; and velveteen, a cotton imitation.

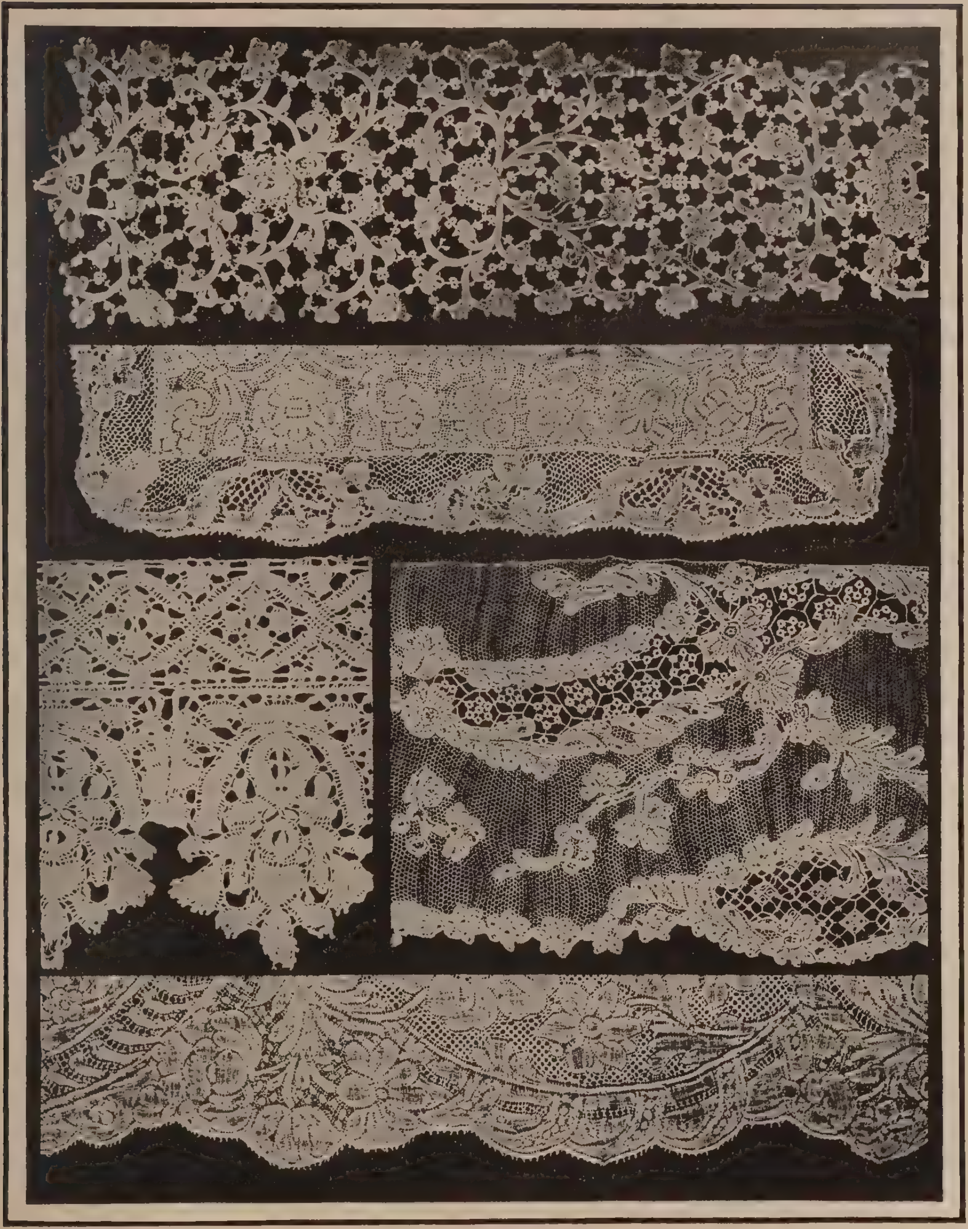
Velvet making of the present day is a very perfect art, many effects being obtained which were never before seen. One is the mirror velvet, woven in more than a single shade and resulting in a changeable surface; another kind is panne velvet, made by pressing the goods after weaving so that the nap is flattened and made to assume a satiny finish.

LACE

WHO does not admire beautiful hand-made laces? The time, labor, and skill required in the making of these exquisitely delicate fabrics render them very precious and costly. Rare old laces are handed down as heirlooms in many a family and are treasured as works of art in the collections of art museums.

The first crude attempts at lace making were made in the twelfth century. By the middle of the sixteenth century it had developed into a fine art, and lace was greatly in demand as drapery for church altars and to beautify the brocade and velvet costumes of kings, courtiers, and great ladies. Modern lace makers can rarely equal the work of the early craftsmen in artistic beauty of design.

There are two ways of making lace by hand. The famous needle-point laces, such as Venetian point, Brussels point, and point d'Alençon, are made with a needle and a single thread. Another kind of lace is called "pillow" lace, being made by working the design over a parchment pattern upon a pillow or cushion, the threads being wound upon bobbins. Mechlin, Valenciennes, Honiton, and Spanish lace are among the more important laces made with the pillow and bobbin.



SPECIMENS OF RARE LACE AT THE BOSTON MUSEUM OF FINE ARTS

Beginning at the top, Rose Venetian Point, 17th century; Valenciennes, late 17th century; Pillow Lace, Flemish or Italian, and Alençon Point, 17th century; Valenciennes, late 17th century.

FROM FIBER TO CLOTH

WE have followed the cotton from its Southern fields, the wool from the sheep ranches of the West, the silk from the mulberry trees of the Orient, up to the doors of our modern mills. Each comes to the mill as a raw product, sometimes as beautiful as the skeins of lustrous silk which the Syrian girls in our picture have spun, but more often as matted and uninviting as the bales of cotton and wool.

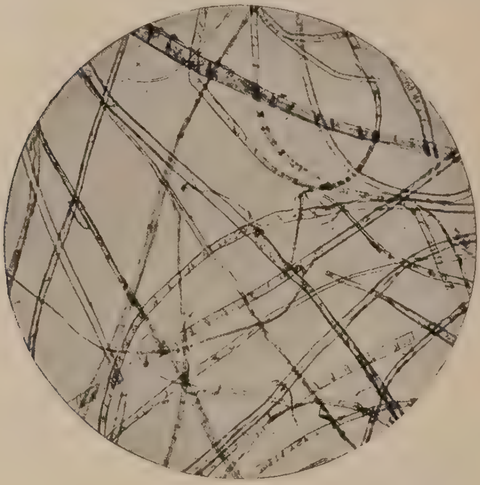


Photo by Gravelle

FIBERS OF FLAX
(Greatly Magnified)

It enters the mill doors and is swept away from our sight into a world of machinery; it comes out transformed into great bolts of beautiful smooth-woven yards of fabric suitable for wearing apparel. The transformation is as complete as in the conjurer's tricks of our youth, and to the uninitiated almost as mysterious. In at one door as a fiber, out at the other as cloth — that is the magic which is worked in our textile factories.

ONE FIFTH OF THE WORLD AT WORK

In her book on "Textiles" Mrs. Woolman tells us that one fifth of the working world is said to be occupied at the present time with weaving, its allied arts, and the distribution of the products of the industry. It is probable that only the food industry surpasses it in the number of its workers. It was reckoned recently that thirty out of every twenty thousand persons in the United States were engaged in the single branch of the business which has to do with the production of wool fabrics. In the cotton industry alone there are probably forty million spindles at work at this instant in this country turning cotton fiber into thread.

THE SIMPLE PROCESSES

The processes of spinning and weaving are among the oldest of human arts. The story of the invention of machinery to do this spinning has been told earlier in this volume. Spinning is the drawing out or twisting of a series of fibers into a long yarn, rope, or cord. Before it can be done the fibers must be opened or disentangled from the mass in which they come, and smoothed for use. This process is called "carding" and is done with an instrument not unlike a comb. "Combing," as the word is used in the textile sense, differs from carding in this way: in the latter process all the fibers are collected together, while in the former only the longer fibers are collected and the short ones are combed away. All raw textile materials must be carded; some are combed and some are not, according to the kind of fiber and the purpose for which it is to be used. In the color plate facing page 233 we see the simplest processes of spinning on a stick or spindle and weaving on a loom.

Weaving is the interlacing of two lines of thread in such a way that they cross each other at right angles. (Look at the pictures of paper and cloth weaving in "Amateur Handicraft," Volume VII, pages 184–192, to see the simplest possible weaving, or at the diagram of a cane-seated chair, Volume X, page 94). In such a pattern the threads that run the long way of the cloth are called the "warp"; those that cross them at right angles are called the "woof." To make short fibers into a smooth, long thread they must be spun; to make thread into cloth the threads must be crossed on each other or woven. Such are the simple and necessary processes on which this whole set of textile industries is built.

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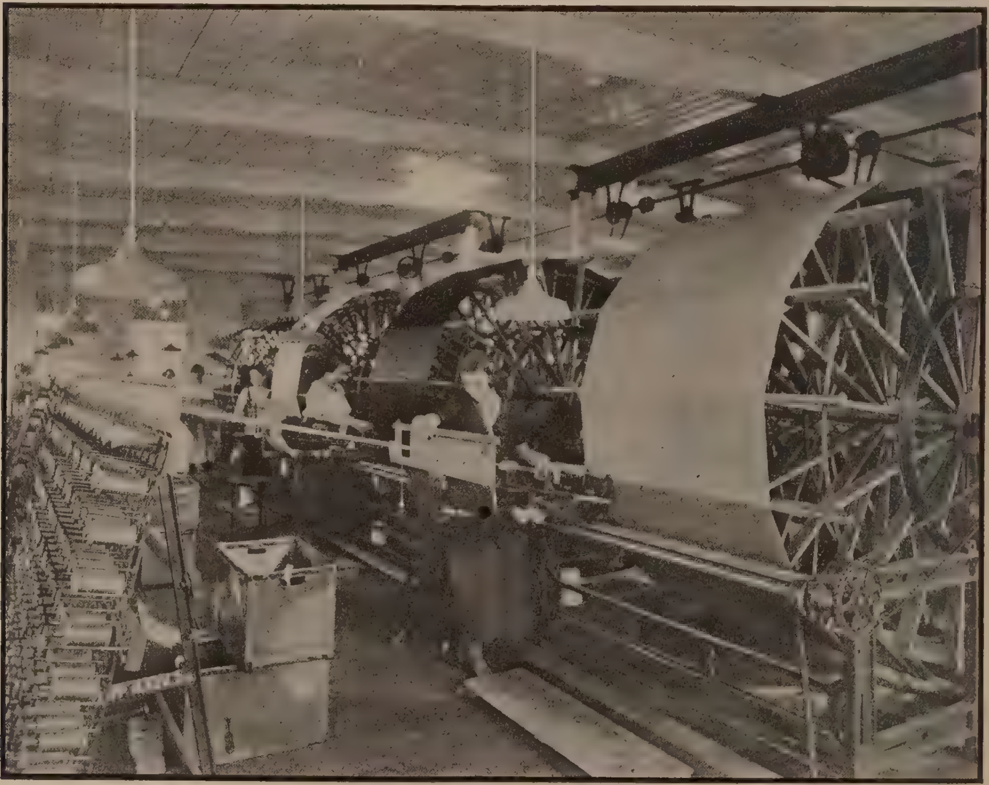
IN A SYRIAN SILK PLANT — EXAMINING AND WEIGHING RAW SILK

TEXTILE MACHINERY

Power spinning and power weaving as practiced by modern machinery repeat the simple hand processes in vastly more intricate ways. It would be impossible to describe these machine methods here; yet we can see in our photographs that the same things are being done by these machines that were formerly done by hand. In the accompanying picture are shown young girls in the warping room of a silk mill, tending machines that tower above their heads. Yet we can see that even on this big scale the warping process is the same as that practiced by the child who lays his threads in parallel lines on a toy loom. The thread is on the dozens of spools at the left of the picture. How many threads shall the operator of the machine lay to each inch-width of cloth? The warp of a light silk may have one hundred to the inch; that of a heavy, four hundred or more. The girl tends and guides these threads as they come from the spools to be laid in parallel lines on the great wheel-shaped machine behind her. The drum above her head may be as large as eight feet in circumference. On this machine we get the first hint of the cloth that is to be. Next it must be woven with a plain weave, or in the case of a fancy cloth with a special and elaborate weave.

THE VARIED OUTPUT

Beyond the simple weaving there is the elaborate pattern weaving done on such marvelous machines as the Jacquard loom (here shown), in which we see the perforated sheets of the pattern held high above the man's head. By a mechanism that is almost uncanny in its capability the threads will be guided into their proper position and relation. Another phase of the industry is the dyeing of all these materials, either in the thread before it is woven or in the cloth at its various stages, and the printing of patterns in color. Any one who goes into a department store and looks at the yard goods as they range from the simplest cottons to the most elaborate figured velvets, carpets, and upholstery or drapery goods, and thinks that all this array



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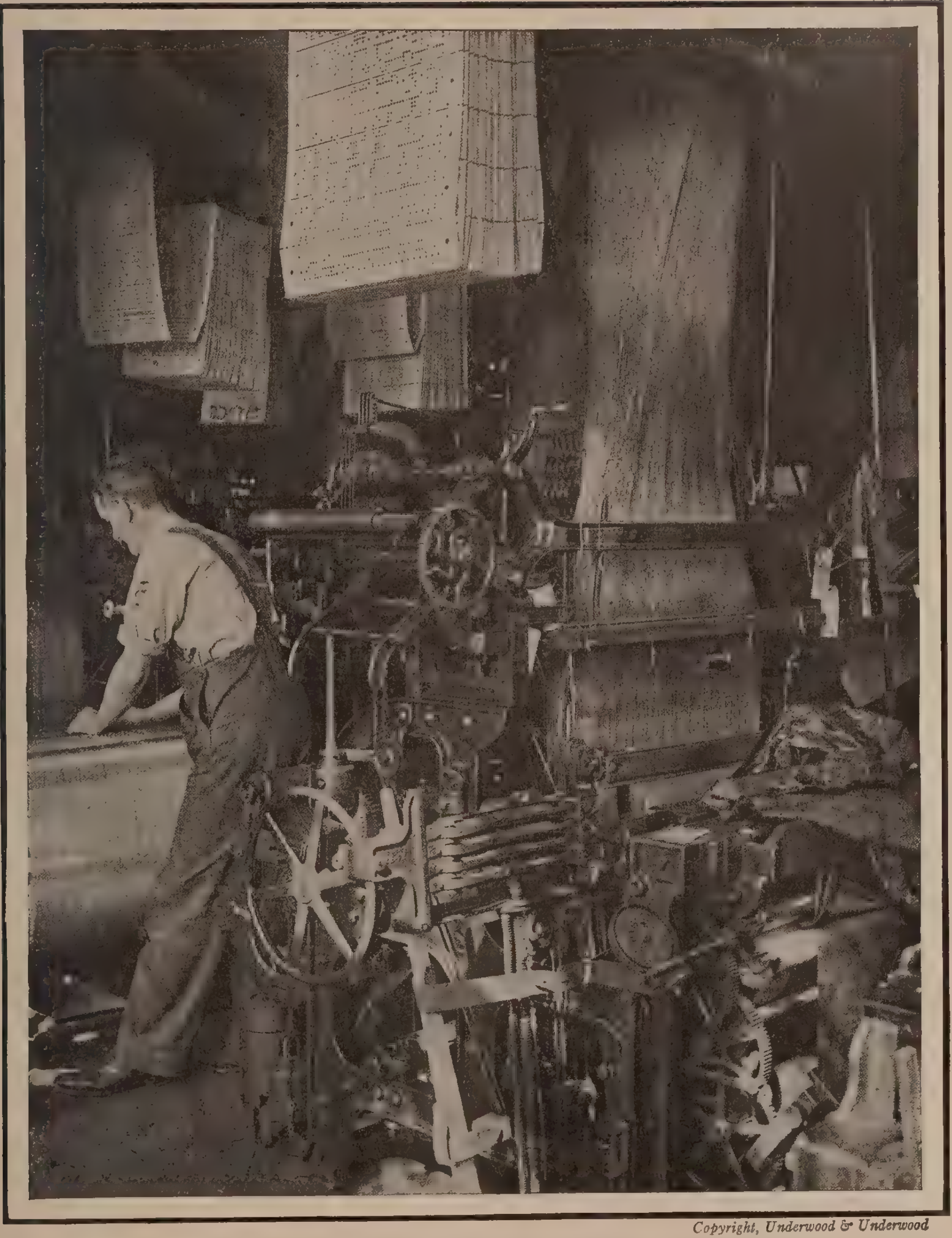
IN THE WARPING ROOM OF A SILK MILL



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THE MARVELOUS JACQUARD LOOM

Used for fancy pattern weaving. Note the pattern sheets unfolding above the machine of brilliantly colored and elaborately woven material came first from the raw products and then from the spool-thread into which they were spun, will come out with a new sense of the contribution which textile machinery makes to our modern world. Nor do the textile industries limit their output to the materials for the home which can be seen in such a store. The fisherman pulls up a woven sail to catch the wind; the electrician calls for woven stuff to insulate his wires; the dentist and the surgeon call for the finest of silk floss; the machinist, for the strongest of conveyor belts for his machines; the automobile manufacturer, for the backing for his rubber tires. It is an endless and ever-varying demand that is made on the textile industries for their products.

COTTON

Each raw material has its own characteristics, which make the treatment of it during the processes of manufacture somewhat different from those of any other. It would be impossible in so simple and brief a story as this to cover the ground of any single textile or any complete process. Yet it is interesting to note at random some of the specialties of each kind of fiber and the results in those finished products with which we are familiar.

We have spoken of the natural twist in the cotton fiber. This helps in the spinning of it, and also makes for a strong thread. The stronger the twist, the greater the elasticity of the fiber. Cotton fiber is stronger than wool fiber. It is, however, soft, and the length of the staple (that is, of the average fiber) is comparatively short. For this reason cotton depends much on finishing processes. Early in the manufacture of cotton cloth it is necessary to apply sizing to the yarn so that it may stand the strain of the weaving. The size is a starchy or glutinous material, like glue or flour, applied in liquid form to the thread, and acts like a glaze. It is often difficult for the purchaser to estimate how heavy a piece of cotton goods really is because there is so much extra sizing which will disappear after a few washings. Besides this simple sizing, cotton goods are treated with many dressings and finishings to produce different effects. The housewife practices one simple method of dressing when she starches cotton garments. A soft finish is obtained by treating with oils; a gloss, as in percales, by applying a mucilage mixture; stiffness, as in linings or organdies, by another formula of mucilage and gums; firmness and weight, as in cretonnes and canvases, by applying a clay preparation.

The fact that cotton takes on a finish so well makes it the basis for many imitations of other cloths. It can be made to acquire a wool finish, as in flannel, or a silk finish, as in mercerized cotton. To mercerize cotton it is treated with an alkali (caustic soda) in a cool temperature, then put under tension, and lastly rinsed. This causes the cotton to become more lustrous, a little stronger and better in color when dyed. This process gives a finish which does not vanish when the fabric is laundered. By heavy pressing or "calendering" a mercerized finish is produced which does not remain after washing. Real mercerization is expensive and adds to the value of the cotton, so that it is well to wash a sample of mercerized goods before buying, in order to find out whether the finish is permanent or not, before paying the extra price for the material. Cotton also combines well as a basis with other fibers, so that we have to-day many cotton and wool, or cotton and silk, or cotton and linen preparations.

WORSTEDS AND WOOLENS

When wool arrives at the factory, it is in fleeces, each fleece having several kinds of fibers — long and short, coarse and fine — according to the part of the sheep's body where it grew. These have to be carefully sorted into piles. The wool must also be thoroughly washed to rid it of a fatty secretion from the skin of the sheep. Woolen goods are of two kinds, — worsted fabrics, which are made of yarns in which all the fibers lie parallel; and woolens, which are made from yarns in which the fibers cross or are mixed. In general, worsteds are therefore likely to be made from the long staple wools, while woolens with their crossed or mixed fibers can be made equally well from the short staple wools. In different breeds of sheep the length of fiber varies from two to twenty inches.

This animal hair requires quite different and in many ways more particular care at every stage in the process of manufacture than some of the vegetable products. It is more subject to variations in temperature; the sorting is particular work; the dyeing, the sizing, and the final dressing are all critical chemical processes. All woolen goods depend much on color for their beauty. The dyeing may be done early in the process, when it is said, in our familiar phrase, that it is "dyed in the wool," or in the thread after it has been spun, or in the piece after it is woven. The beauty of woolen goods comes in large measure from the finish of the cloth, while that of worsted goods lies in the weave.

So many are the processes of finishing which give the soft finishes and pleasing luster to the many kinds of wool materials that the buyer is in danger of being confused as to the real value and quality of the goods.

WHAT IS SHODDY?

The world's wool supply is not sufficient to supply new wool for all the goods required. Consequently there is a great business of reclaiming old wool and using it again. "Shoddy," as this recovered wool is called, may be very good or may be very poor. There is frequent agitation before Congress to have textile goods, and especially wools, labelled with the percentage of the pure raw product in them. On the whole, the purchaser's reliance should be on the judgment and honesty of the retail merchant, who makes a study of textiles, knows the firms with which he deals, and is ready to advise as to the worth of his goods. Even he may be misled, for the modern treatment of goods by chemical and mechanical processes works in two ways. It gives us beautiful and varied finishes for our fabrics, but it also makes possible the concealment of defects which would have been very evident in the old-fashioned "homespun."

SILK

Of the weaving of silk we have spoken in some detail in our earlier story. Silk holds a safe lead among textiles because of its strength, its light weight, its fineness of weave, the smoothness which makes it shed dust, and its luster. Pure silk is so beautiful that it needs no dressing, only the bringing out of its own natural sheen. The cheaper silks take up a good deal of dressing, which, with the skill of the modern chemist, gives almost the effect of the pure original. The poorer of us may now go clothed in silks and satins of a quality that will give reasonably good wear, while the richer may still indulge in the most beautiful of pure silk fabrics.

LINEN

No story of textiles would be complete without a mention of linen, a vegetable product corresponding to cotton, made from the fiber contained in the stalk of the flax plant. No matter what the combinations of other goods and the finish put on other materials, linen holds its own. Pure linen stands preëminent on account of the properties of its fiber, which it carries on into the finished cloth. It is naturally smooth; the fibers are very strong, and therefore wear well; water evaporates from it quickly, which makes it desirable for towels and handkerchiefs; it cleanses well and stays white, which makes it ideal for tablecloths and napkins; it has a good luster of its own. It was one of the misfortunes attendant upon the Great War that so much land previously under cultivation for flax abroad was turned to other uses. It is to be hoped that flax culture will be resumed in our own and other lands, for linen is a cloth for which there is no adequate substitute.

KNITTING

One more process of manufacture should be added to our textile list. The old hand process of knitting, with which we are all familiar, has been adapted to machinery, and an increasing number of knit goods, from sweaters to underwear, hosiery, and yard materials, is found on the market each year. Knitting, as distinguished from weaving, is the interlacing of yarn or thread, not by laying them at right angles to each other but by running the thread through a series of loops, each catching into the stitch before it. This, too, can be done effectively by machine methods, and there are many knitting mills in various parts of our country.

FOOD FROM FAR AND NEAR

FOOD is man's first and most pressing need; the food business is therefore his chief industry. From the wheat fields of the Far North, where the growing season lasts only a few brief weeks, to the regions of the tropics, where there is summer all the year round, men are busy at the task of planting, raising, harvesting, and distributing food. It is an industry with some part of which all of us are more or less familiar. To cover it adequately and thoroughly would require more volumes than this or any other set contains. Yet if we touch on certain basal American industries, like that of wheat, and certain imported products, like tea and coffee, and certain luxuries which have become necessities, like sugar, we shall get the two pictures which we should carry away from any study of food industries, — the first, of the wonderful fertility of this world in which man has been placed by his Creator, and the second, of the wonder of modern commerce which brings to our tables as everyday supplies articles of food which have been raised hundreds and thousands of miles away.

THE CHIEF PLANT INDUSTRIES

Since plant food is the basis of all that we eat, man's first dependence is on the soil. The farmer is therefore the most important of all industrial workers. Every other worker depends for his very life on the products which the farmer supplies. The farmer in his turn must cultivate his soil with all care and skill, so that it will continue to yield the products on which he depends.

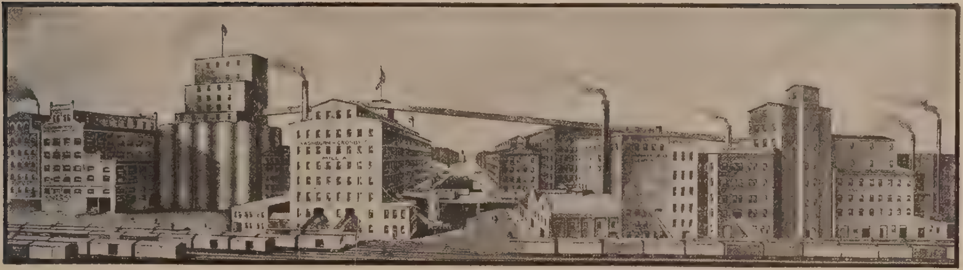
First in the list of plant products come the grains, — wheat, which we have discussed in an earlier chapter, but which we shall now see turned into flour for bread; corn, used in our country chiefly as food for the animals which will supply man's meat; rice, the grain of the tropics and the principal food of half the world, grown to a considerable extent on the coast and river lands of Louisiana, Texas, California, Georgia, and South Carolina; and oats, barley, rye, and buckwheat, which are all grown for their different uses in some parts of the United States and Canada. Another type of industry is that of sugar, which we discuss in a later chapter. The fruit crop of the United States is one of the sources of its wealth, as well as of its people's health, for fruit supplies elements in our diet which give needed nourishment as well as pleasing variety. Increasing attention is paid in this country to the raising of nuts. Last of all, vegetables are among our most varied and staple products, being raised all over the country on a small scale as well as a large. (See also Volume X, pages 225–242.)

ANIMAL PRODUCTS

Animals eat plant foods and combine them in their bodies into animal foods on which man depends for his nourishment. How they do it you will find discussed in the story of "The Wonder of Life" in Volume XI.

Our meat comes from the flesh of cattle, hogs, and sheep, the raising of which is an enormous industry or group of industries. Cattle raising was one of the most picturesque and interesting early occupations in this country, and is one of the most important of our present ones. It is the source for the raw product on which is built another of our great modern industries, that of meat packing. No one can speak of any of these great branches of the food business without running into figures of hundreds of thousands and millions, either of hogs and sheep raised for slaughter, or of cattle grazing on the ranges before they are sent to the stockyards, or of dollars invested in what is one of the keystones of modern business. Along with the raising of cattle for meat is the great business of dairying, which is extremely important in a country where we are as dependent on milk and butter as in the United States. Poultry and eggs make other chapters in the story of animal products. (See Volume X, pages 163 and 245). We have already touched on the wealth of the waters as it is gathered in by fishermen.

Such in brief is the relation of the American and the Canadian to the food business of the world. We live in a land of unexampled plant and animal wealth and are able to be reasonably independent in the production of the staples. But we are engaged in a business of trade and interchange which brings us foods from every corner of the world.



FLOUR MILLS OF THE WASHBURN-CROSBY CO., MINNEAPOLIS

FLOUR

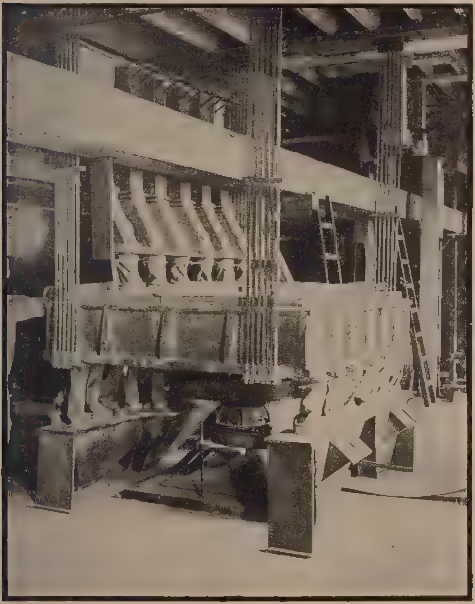
THE process of turning the raw wheat into the flour of which we make our bread is called "milling," and it is one of the greatest of American industries. In very ancient times saddle stones were used for grinding wheat into flour, the wheat being placed in a hollow stone and rubbed with a rounded stone rocked backward and forward. Half-civilized people of

PACKING FLOUR AT WASHBURN-CROSBY COMPANY'S MILLS. DAILY CAPACITY, 35,000 BARRELS

TOP: HEATING THE GRAIN IN ROTARY HEATERS. BOTTOM: BRAN DUSTERS IN WASHBURN-CROSBY COMPANY'S MILLS to-day still use them. About the beginning of the Christian era stone crushers, called "querns," were used. Many years afterward specially hewn millstones, moved by slaves or oxen, were introduced. Later, water wheels and windmills were used as motive power for the millstones, and lastly steam.

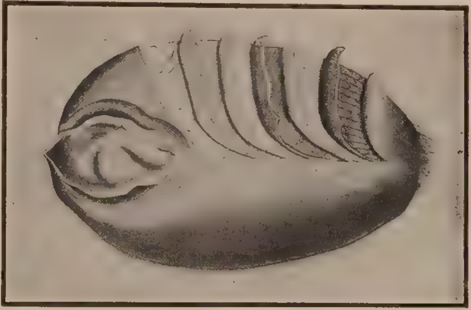
What a contrast between those primitive flour mills and the wonderful mills of to-day! In these great buildings the wheat is ground between many sets of steel rollers, passing automatically from one set to another.

As late as 1870, however, the flour of America was still being ground between millstones, and it was a much inferior grade of flour to that produced to-day. The roller process was introduced from Hungary in 1870, and revolutionized the American milling industry. By the old process of grinding between millstones, it was hard to separate the " middlings " of the wheat kernel from the bran, although they are rich in the gluten that gives wheat flour its chief value in bread making; hence, the middlings were wasted. By the roller process they are saved and produce the high-grade patent or white flour of to-day, with greatly enlarged profits to the manufacturers.



A PLAN SIFTER AT WORK

The middlings are that portion only of the kernel between the bran covering and the starchy central body. When the entire wheat kernel is ground into a meal it is called "graham" flour. When a portion of the bran is removed, but the germ and fine bran are retained, the product is called "entire wheat" flour. It was believed for a good many years that graham and entire wheat bread were more wholesome and nourishing than plain white bread, but this theory is no longer universally held. Many believe that white flour bread, because more digestible, is as nourishing as the graham or whole wheat bread.



A DISSECTED KERNEL OF WHEAT, MAGNIFIED

Important milling cities are Duluth, St. Louis, Toledo, Buffalo, and Chicago. But these are all far outclassed by Minneapolis, the greatest flour-milling center, not only of the United States, but of the whole world. Situated on the Mississippi River, at the Falls of St. Anthony, it has the advantage of unrivaled water power, and is besides the gateway of the great wheat fields of the Northwest. Moreover, Minnesota and Dakota spring wheat is especially rich in the gluten that makes fine white flour. With the introduction of the roller process into Minneapolis mills, this hard spring wheat, so unprofitable to grind under the old system, took its place as the best flour material in the world. For every million barrels of flour produced by other cities, Minneapolis produces about sixteen millions.

TEA GATHERERS, NEAR KYOTO, JAPAN

THE FRAGRANT TEA

"Polly, put the kettle on,
And we 'll all take tea."

TEA drinking is a very old Chinese custom; just how old we do not know. Long before anyone else had heard of tea it was in use among both the Chinese and the Arabs. Certainly the Arabs were using it as early as the ninth or tenth century. But it was not until 1610 that the first tea was brought from China into England, where it sold for four dollars a pound. Later a trading ship came bringing four thousand pounds of tea. The English, however, did not know how to use it, and it took them many years to find out. A story is told of how some English people invited their friends to have tea with them and cooked the tea, drained off the water, and served the leaves with salt and butter. Do you wonder that their guests did not like the taste of the new dish?

Yet at the present time, in other countries, tea is still served in many surprising ways.

In Tibet it is stewed with pork, salt, flour, and milk; after cooling, it is eaten as if it was some sort of porridge. The Russians pickle tea, or drink it cold with lemon in it, holding a piece of sugar in their mouths to sweeten it. Natives of other lands chew the tea leaves, and some mix them with sugar and cook them into a sirup. Tea is now such a common drink that it is hard to realize that there was a time when people did not have it. It was not until the eighteenth century, when tea drinking became popular in England, that the custom was taken up in America and other parts of the civilized world.

TEA PLANTS AND WHERE THEY GROW

Although the tea plant was originally a Chinese shrub, a different variety of it was found to be growing in Assam, India, and it is from these two kinds that our tea comes. The Chinese plant is not so tall as the Indian, for it is usually only from three to five feet high; the Indian species, if not clipped, often grows to be fifteen or twenty feet in height. But since tea must be picked by hand the tea bushes are kept low so that the pickers may reach the branches easily. Both trees are evergreens, the leaves on the Chinese plant being about four inches long, while those of the Indian variety are sometimes as long as nine inches. Chinese tea plants are stronger and more easily grown, and therefore are more in demand. And yet tea is by no means a difficult plant to raise. It will grow in almost any soil, but of course in the warm, moist earth of the tropics it thrives best. It has, however, been raised in England and even in North Carolina. The chief difficulty is that, as all the work of cultivating, gathering, and preparing it must be done by hand, it is a very expensive crop to harvest in countries where labor is not cheap. In India, China and Japan, where living is simple, natives can be hired for very little. Twice a day the tea gatherers, some of them often being children, bring the tea they have picked into the factories, where their baskets are weighed.

Pickers are paid by the pound, a quick picker frequently gathering from twelve to eighteen pounds a day; many do not gather as much as this. A few cents pays for the labor of picking.

HOW TEA IS RAISED

Tea is started from seed, and when well up the small plants are transplanted and set out in rows. The plants must then grow about three years before they are old enough to be of use. When they are older they throw out offshoots called "flushes"; these flushes have seven or eight leaves, some small, some larger. The leaves of the new shoots are the only ones gathered for market. As soon as one set of flushes is harvested another set grows, until as many as twenty-five sets of new leaves follow each other on a single plant. The finest tea is made from the tender leaves, and in China these are generally gathered in February or March, while still protected by a fuzzy white down called *pakho;* it is from this word that we get the word *pekoe* — the name of one of our most expensive varieties of tea. The cheaper

Courtesy Chase & Sanborn

PICKING GREEN TEA LEAF

teas are made from the larger, tougher leaves of the plant. In some countries tea harvesting goes on all the year, seasons for picking differing with the climate.

Before marketing tea, therefore, you can readily see that the leaves must all be sorted. Sometimes this is done when they are picked, but more often the gatherers take off the entire tip of the branch and the leaves are sorted according to size afterward.

HOW TEA IS PREPARED FOR SALE

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TEA PLANTATION AND RICE FIELDS, JAPAN

The first step in preparing Chinese and Japanese tea is to spread it in large trays and leave it in the air. Here it soon begins to ferment, and it is this fermentation which decides the flavor of the tea. Men trained in preparing tea can tell by the odor exactly how long to let the leaves lie in the air. Think what a difficult task that must be! It is while the tea is fermenting that some of the tannic acid in it is turned into sugar; it is this sugar that helps to give the tea its flavor.

When the leaves have aired long enough they are put into dishes and slowly roasted over a hot fire of charcoal. Then they are taken off and the natives roll them in their hands to squeeze out the juice. Afterward they are again roasted and again rolled, and this is done over and over until the moisture is out of them. They are then spread on sieves over a fire and stirred and turned until entirely dry. The black color comes in this last drying, although it has been preparing to do so throughout the whole process.

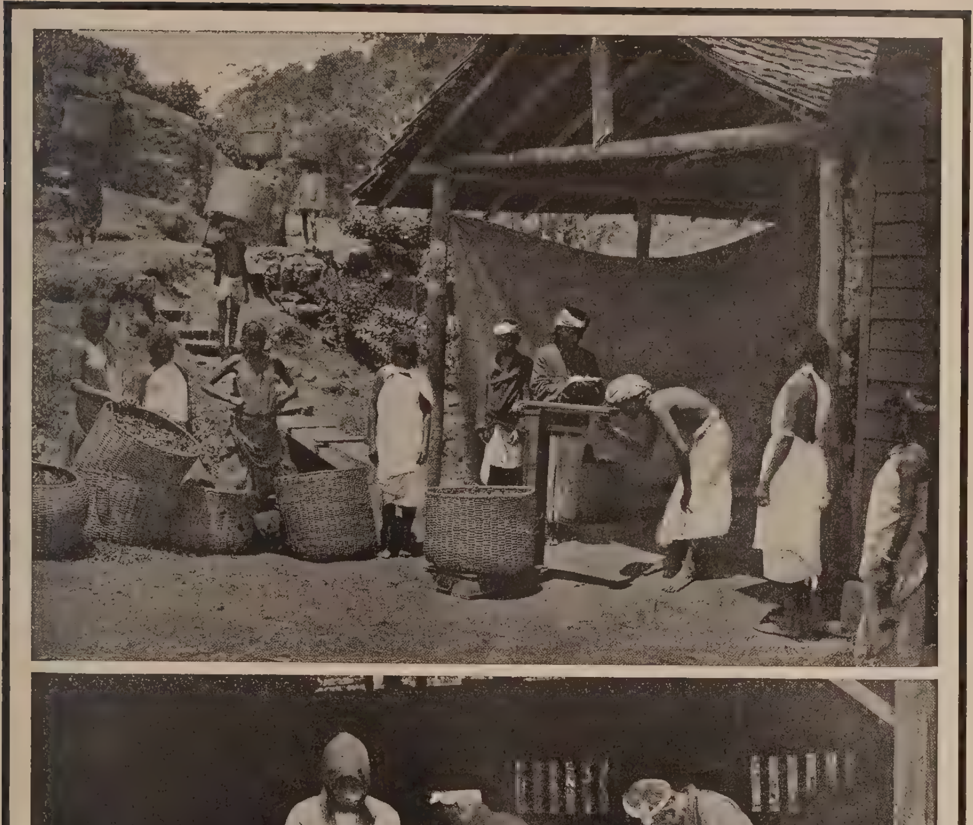
The tea is then packed in lead-lined boxes or chests, that none of its flavor may be lost, and it is ready for shipping.

In olden times tea used to be brought across the deserts by caravans, and it was a wonderful sight to see great processions of camels, laden with oriental merchandise, making their way from the East; but now we employ the fastest ships to carry tea, as buyers feel that even at best the tea loses some of its flavor in transportation.

Green tea is manufactured by much the same process as black tea. Its green color is due to the fact that the leaves are not allowed to wither, but are quickly roasted while fresh. Most of our green tea, unfortunately, is colored with dyes and is not really green tea at all. Such tea is unwholesome and should be avoided. The Chinese people drink four times as much tea as all the rest of the world put together. Like the Japanese, they drink their tea clear. But in England, another great nation of tea drinkers, sugar and cream are generally used. Possibly this custom is a relic of those far-off days when the English made their tea leaves into porridge and ate them with sugar and cream.

HOW THE NATIVES OF INDIA PREPARE TEA

In India tea is prepared differently from what it is in China. After it has been picked, aired, and fermented it is made into damp balls and workmen roll and knead it on tables. Then it is pressed into great lumps and put away to ferment again. When it has fermented long enough it is either roasted over a hot fire or

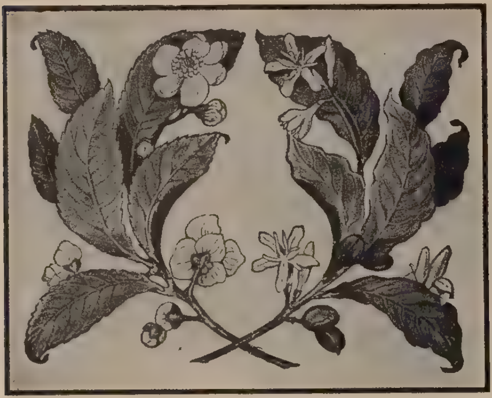


Courtesy Chase & Sanborn

TOP: WEIGHING THE GREEN TEA LEAF PICKED DURING THE DAY. BOTTOM: WEIGHING TEA dried by machinery. Afterward it is sifted, sorted, and sealed for market.

PRICES OF TEA

There is a vast range in the price of tea. Coarse teas can be bought for a low price; teas made from the flowers of the tea plant, however, often cost from sixty to eighty dollars a pound. What do you think of that? In Russia valuable tea is frequently made into solid cakes, about the size and shape of a brick, and these bricks of tea sometimes reach as high a price as two hundred dollars. The most costly teas are packed in glass, brocade, or lacquer boxes fastened with bits of ivory or silken cord, and look much more like caskets of jewels than packages of tea.



TEA AND COFFEE PLANTS

THE EXHILARATING COFFEE

THERE are many interesting stories of how people first found out that coffee was good to drink. One of them is that very long ago an old Arab sheik wandered into Persia and was there taken very ill. A Persian sage brewed for him a drink made from the berries of a wild herb growing in the fields, and this strange hot beverage brought about the recovery of the Arab.

After he became well again he returned to his own land, carrying with him some of the berries of the shrub that had cured him. These berries he planted, sharing them with his friends. Thus was coffee introduced into Arabia.

Whether there is any truth in this story it would be hard to say. Certain it is, however, that coffee drinking had its origin with the Arabs. Since the Koran forbade them to drink stimulants made from alcohol, they no doubt were glad to find this substitute. In the sixteenth century the Turks and Arabs in Constantinople were all familiar with the use of coffee, and carried the custom with them to Venice, then one of the great cities of the world. From Venice it traveled to Paris. Later London welcomed it with open arms. In the seventeenth century the coffee house was the popular resort not only of the idle and fashionable men of the time but of scholars and statesmen as well. Here people congregated, sipped a cup of steaming coffee, and discussed the news of the day, the coffee houses occupying much the same position then that a gentlemen's club now holds.

America was the next country to take up coffee drinking. The English have since reverted to tea, and use it much more generally; but coffee is still the popular drink on this side of the ocean.

HOW COFFEE GROWS

In Peru, Persia, and western Africa coffee grows wild in the fields. It takes its name from Caffa, a town in Abyssinia, where its valuable properties were first noticed. It is now widely cultivated in India, Arabia, Mexico, and Brazil, the latter country alone supplying more than half the coffee used by the entire world. You notice, therefore, that it is in the tropics that coffee has its home. It needs heat, richly fertilized soil, and very deep earth in which to grow.

Like the tea plant, coffee is started from seed, and when large enough is transplanted in rows from six to eight feet apart. Until coffee plants send out branches which can shelter their own roots they must be cared for constantly. This danger point safely passed, they become quite hardy. In growing the plants the same plan is followed as in pruning tea bushes. The tops of the shrubs are cut in order that branches may be forced to shoot out at the side. This

GATHERING COFFEE IN BRAZIL

More than half the world's coffee comes from the plantations of Brazil. When picked the berries are dark red like cherries.

WASHING COFFEE IN BRAZIL

All that remains of the outer pulp must be rinsed off the berry.

DRYING COFFEE IN THE SUN, COSTA RICA

is for the convenience of the pickers, who must gather the coffee berries by hand.

Although some young coffee plants blossom and yield fruit in the second year, they cannot be relied upon to do so until the third. Then, when spring comes, beautiful white blossoms with a strong, sweet perfume bloom on the coffee plants.

When this bloom drops it leaves a small soft seed on the stem, which is not unlike a cherry in formation and size. The soft part of this fruit is useless, but in its center are two coffee berries which fit together and make a sort of stone. These are what you have so often seen roasted and ground.

TURNING THE DRYING COFFEE, ARNABA, MEXICO

THE WAY COFFEE IS MADE

As soon as the blossoms of the coffee plant fall, and the cherries ripen, pickers are turned into the plantations, and move from one plant to another, gathering the dark red and slightly shrunken cherries in bags. These bags the pickers afterward empty into a common receptacle.

ASSORTING COFFEE, NICARAGUA

Picking is slow work. When a picker gathers two or three bushels of cherries a day he is doing well. Since only the ripe cherries are gathered, the pickers are constantly obliged to retrace their steps and glean the rest of the fruit as fast as it matures. This work is hard and poorly paid.

After the cherries are gathered the coffee berries must be taken out of the center. This is done in a mill. Sometimes it is possible to float the cherries down to this mill through pipes of running water. If they are sent down from the hillsides in this way large sieves, or screens, are placed at the ends of the pipes to

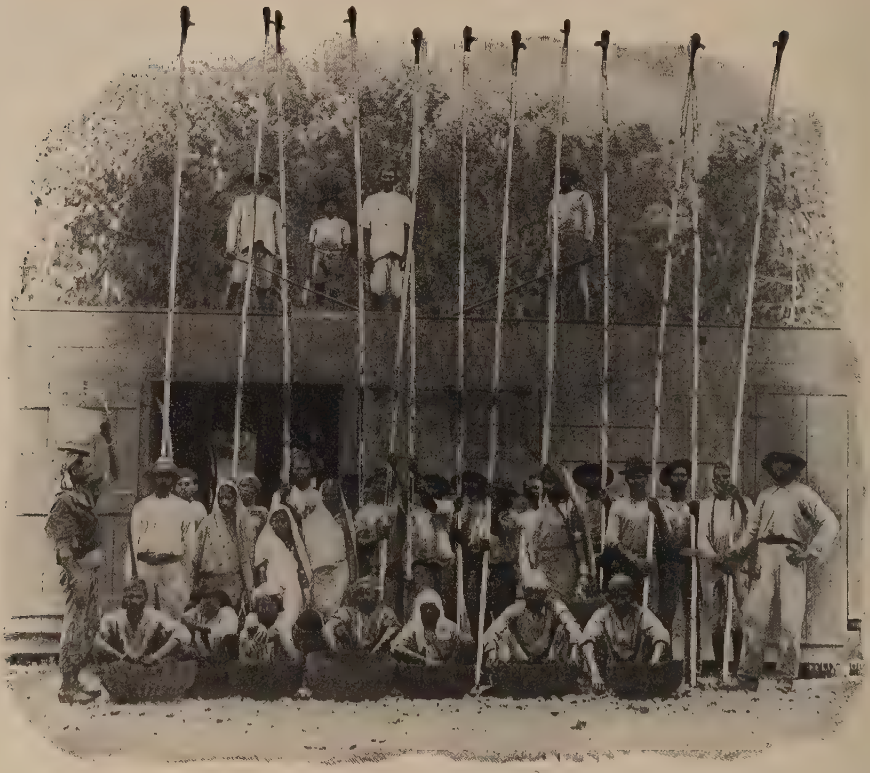
Courtesy Chase & Sanborn

HAND-PICKING COFFEE

filter off the water and collect the fruit. The pulp, or soft part of the cherry, is removed by placing the fruit between revolving disks which tear it apart and separate it from the coffee berries. Some manufacturers think this should be done promptly before the soft pulp has a chance to ferment. Other growers let the pulp dry on, and later remove it by machinery. When the cherries are dried in this fashion they are put in the sun and stirred until the pulp shrivels. They can then be shipped to distant mills. This is a convenient process and is especially favored by those growers who either cannot afford mills, or have not the facilities near at hand to run them. When the pulp is not allowed to dry on but is removed from the fresh cherries, much soft matter clings to the coffee berries; the easiest way to get this off is to let it ferment and then rinse it off with water.

The clean coffee berries, or beans, are then dried by the sun or by means of hot air. When the bean is dry a thin coating, not unlike the inside skin of the peanut, covers it; this is known as the "silver skin," and it is removed by rolling the beans until it cracks off. The beans are next placed in a sorting machine which drops those of the same size into boxes. The raw coffee — or, as dealers say, "green coffee" — is now ready to be shipped. No coffee is ever roasted before shipping, as it soon loses its flavor. Green coffee, however, may be kept indefinitely and becomes better with the keeping. Old coffee is considered a great delicacy.

COFFEE TREE WITH RIPE BERRIES



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GROUP OF NATIVE COCOA PICKERS

THE REFRESHING COCOA

WHEN Cortez came to Mexico he found the Mexicans making a delicious drink that he and his followers had never before tasted. In fact, so fond were the Mexican people of this beverage that Prescott, the historian, tells us that the Mexican king Montezuma, who lived in great splendor at the capital, often had as many as sixty jars of the drink made for him and his court; it was served very hot and taken from golden goblets. Upon investigation it was found that this new dainty was prepared from the seeds of a kind of tree growing in the tropical parts of South America. The Mexicans called it "cacao," and it was nothing but the well-known cocoa which we all like so much.

Cocoa grows on a small tree, or shrub, from fifteen to eighteen feet high, having large, smooth leaves and clustering flowers of pinkish white. Sometimes these flowers blossom on the branches, sometimes shoot out of the trunk of the tree itself. Strange to say, they do not blossom all at one season, but continue to bloom at intervals during the entire year. Consequently the fruit is maturing all the year round, although the principal times for gathering it are in June and December.

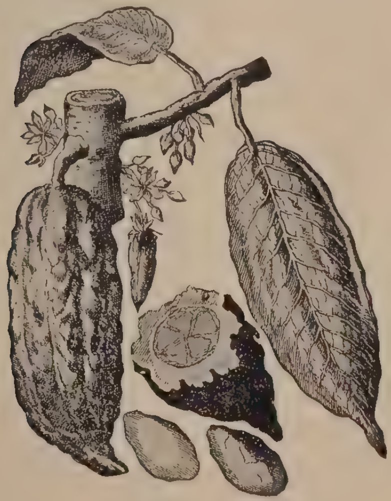
HOW CACAO TREES ARE SET OUT AND GROW

Cacao trees are grown on plantations similar to those where coffee is cultivated, and like coffee plants the cacao trees are also raised from seed. Cacao plants, however, are rather delicate and are not transplanted from the nurseries until they are about two feet high;

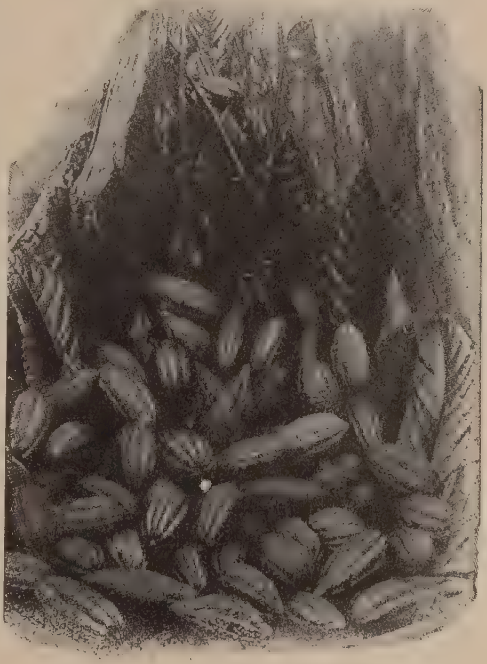
even then they must be protected from hot sun and strong winds. In order to shelter them the growers often set out hardier things in the same field, that these may cast their shade over the cacao plants and at the same time serve to break the force of the winds. Until the fourth or fifth year not much fruit can be expected from the young cacao trees, and it is not until the eighth year that they really bear a good crop; but when they have once begun to yield a harvest they go on bearing abundantly for from thirty to forty years. After the cacao trees have flowered each flower sends out a pod not unlike a cucumber in construction; each of these pods is from seven to ten inches long, and has inside rows of cells filled with sweet pulp. Embedded in the pulp are from five to ten seeds. Some pods will contain twenty-five or even fifty of these seeds altogether. The seeds are about the size of an almond.

GATHERING AND PREPARING CACAO

Laborers travel up and down through the rows of cacao trees selecting the pods which are ripe, and cutting them off by means of knives mounted on long handles. As soon as the pods fall the workmen catch them that the fruit may not be bruised, and heaping them in piles leave them for at least a day to dry; the pods then soften and it is easy to cut them open and take out the seeds.



COCOA PODS AND LEAVES



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COCOA PODS, EACH SEVEN TO TEN INCHES LONG

As is the case with both tea and coffee, fermentation aids greatly in the preparation of cocoa and has much to do with its flavor. The seeds ferment either in sweating-boxes or in the ground for two or three days, when they are placed in the sun and dried; it is then that the cacao beans gradually turn the beautiful chocolate brown color that you are accustomed to see. After drying they are shipped to the market in bags.

Before using cocoa, however, the seeds must be roasted in revolving cylinders and afterward placed in machines which crush them into small pieces called "nibs." Then the pieces of cracked cocoa or nibs must be separated from the shells by blasts of air. It is necessary, as a last step in the process, to sift the nibs, or have them

Courtesy the Royal Mail Steam Packet Company

GATHERING COCOA AT TRINIDAD

The ripe pods are cut by knives on long handles, then gathered and heaped in piles to dry, when the seeds are taken out sorted by hand, that all impurities may be taken out.

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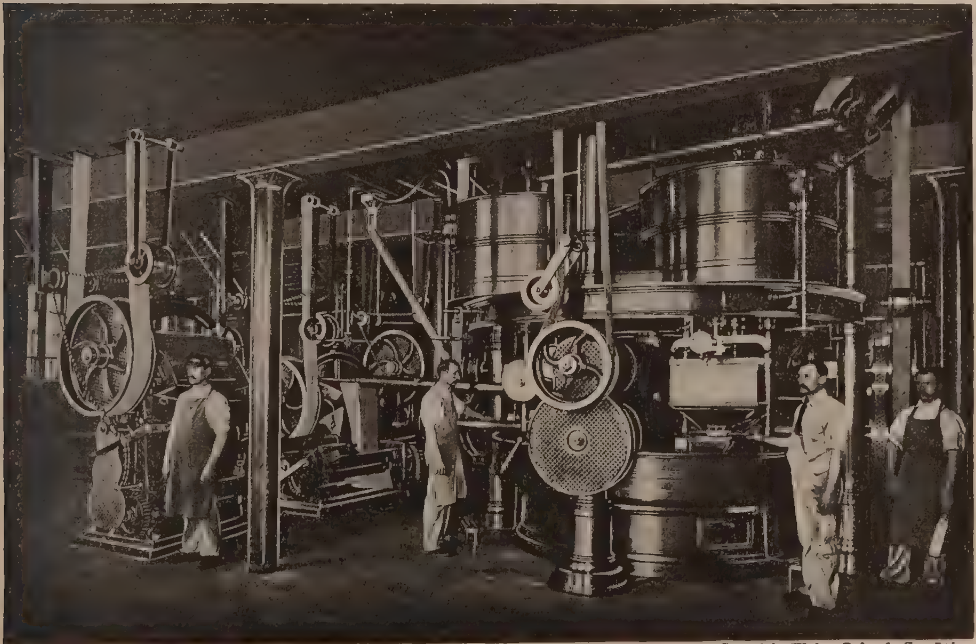
A MOLDING ROOM IN A MILL

Cocoa can be made from the nibs by boiling them a long time, but as it is found to be much easier to make the drink if the nibs are ground to a powder, this method of preparation is generally in use. The powdered cocoa is always put up in tin cans to prevent the moisture getting in and making it damp or lumpy. You all know without doubt that when the powdered cocoa is mixed to a paste, pressed down between heavy rollers, and hardened in molds it is called "chocolate." Chocolate may be unsweetened, or sweetened with sugar and flavored with vanilla. You also know the many pretty shapes into which chocolate may be fashioned, and the delicious things that can be made from it. Think for a moment of the chocolate creams, bonbons, and caramels we eat during the year!



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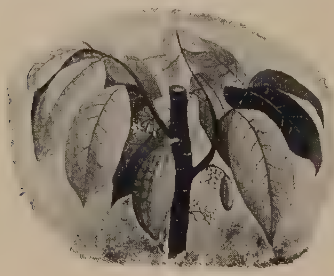
A CHOCOLATE MACHINE

These chocolate candies are not altogether bad for us if we do not eat too many of them at a time. In fact, so great is the food value of chocolate that persons going on long walks or on journeys frequently carry it in place of food. It is also in use among mountain climbers, and has an important place in the food rations of armies and exploring expeditions, because of its nourishing qualities and because it can be carried in such small space. Dr. Nansen, the famous Arctic explorer, in his book, "The First Crossing of Greenland," speaks of the large use made of chocolate by the members of his party. Cocoa beans are about half composed of a rich fat which, when extracted in manufacture, is made into cocoa butter — a healing remedy much employed by physicians. Since a portion of this fat, as well as more or less starch, is found both in cocoa and in chocolate, it is not difficult to see why they are valued as foods.

Although the Mexicans used cocoa so long ago, it was not until 1657 that it was at all known in England. We read that at that time there was in London a fashionable resort — a kind of coffee house — called the Cocoa Tree, where hot chocolate was served. About the beginning of the eighteenth century chocolate had become an exceedingly popular beverage, and the cocoa tree was then a favorite sign and name for the places of public refreshment. Chocolate was first manufactured in this country in 1765, in the State of Massachusetts. At the present date the French, Germans, British, and Dutch use far more cocoa than do the Spanish. This great supply for the world comes chiefly from our Western Hemisphere, the Caracas cocoa from Venezuela being considered the best.



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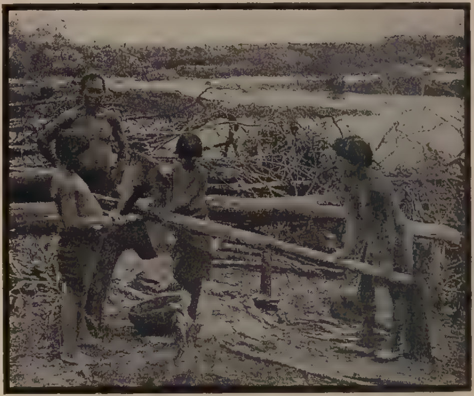
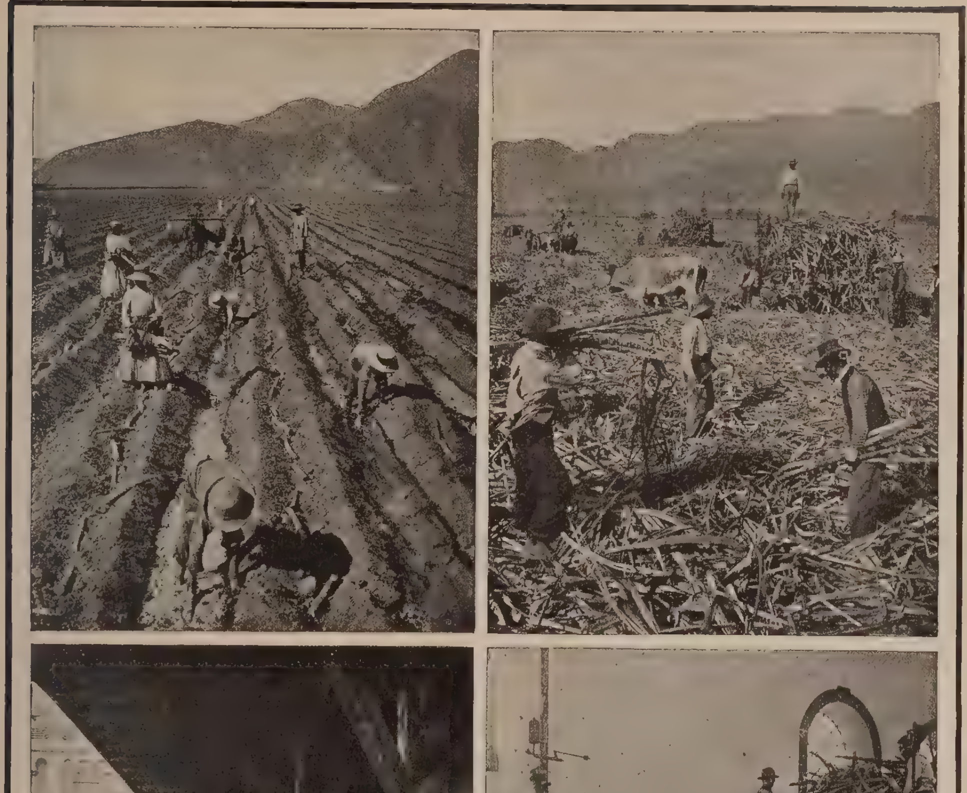
SUGAR — FROM CANE TO CRYSTAL

HOW would you like to have lived in the days when tea and cereals were sweetened with maple sugar, brown sugar, or honey, and when white sugar was such a luxury that no one thought of using it commonly, but kept it for a treat or a medicine? Such days were not very long ago. Our grandmothers still remember them. At that time money was not so plentiful as it is now and, as but little sugar was made, and most of this came from other countries, people could not afford to buy it. Sometimes the children were allowed to have it on their bread, or eat some of it in place of candy. Perhaps mothers realized that sugar is needed by all children as fuel for their bodies. The children, of course, did not dream that more than half their energy was generated from the sugar taken into their systems, nor know that this was the reason why they wanted it just as our children do to-day. Children now eat three times as much sugar as their parents used to eat. In fact the United States has become the greatest sugar-eating nation of the world. On an average each person eats in some form or other about eighty pounds of sugar a year — much more than the Germans or French. It is only because the English use so much to make jams that they approach this record. One reason why so much sugar is used in America is be-



A PRIMITIVE SUGAR MILL OF THE CAURA INDIANS

The cane is squeezed between a pole used as a lever and the surface of a deep notch in a post, the juice trickling down into a rough wooden bowl.



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TOP: IRRIGATING STERILE PLAINS AND PLANTING SUGAR CANE; HARVESTING THE CANE. BOTTOM: FEEDING THE CANE INTO AN ENDLESS CHAIN WHICH CARRIES IT INTO THE MILL; GRINDING OR PRESSING THE CANE IN THE MILL, SANTA CLARA, PERU

Courtesy The Louisiana Planter

SUGAR CANE GROWING IN CUBA

cause in the United States almost everyone can afford it. No other people use it so commonly in food, or eat such quantities of it in candy. Certainly we do not lack fuel to create the energy for which we as a nation have become famous. But not all the fuel taken into our bodies comes to us through ordinary white sugar. There is some sugar in almost every growing plant, and therefore much in other foods which we eat. Grapes contain a great deal; so do milk, maple sap, beets, the juice of the palm tree, and the sugar cane. From all of these sugar may be extracted, but it is from beets and sugar cane that we get the most.

WHERE SUGAR CAME FROM

Centuries ago sugar cane grew only in southern Asia, and it was the Chinese alone who found out what to do with it. They did not make sugar like ours, but they did use the sap for sweetening purposes. The other peoples of the world used honey. It was the Crusaders, those fighters who brought so many wonderful new things back into Europe, who first carried sugar cane to northern Africa and later to Madeira and the Canary Islands. For many years the sugar for all Europe came from the Canary Islands. Then the Western Hemisphere was discovered and plantations were started in the West Indies. South America next took up the industry, and later it spread to the tropical districts of the United States. Now most of the cane sugar raised in our country comes from Louisiana and the delta of the Mississippi River. Since, however, we consume so much, there is not enough to fill our demand even with the addition of the beet sugar we make, and we are forced to import a great deal from Porto Rico, Cuba, the Philippines, and Hawaii.

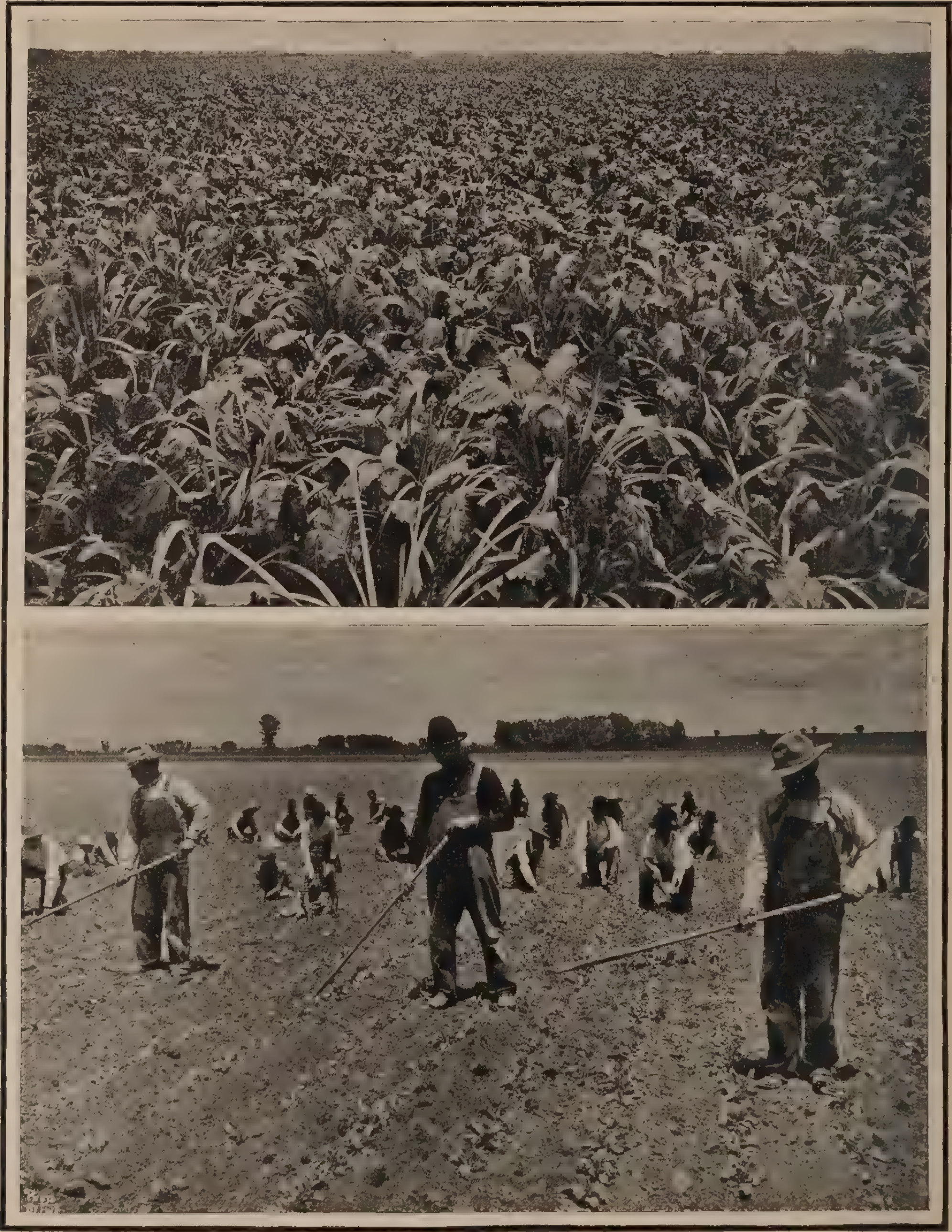
HOW SUGAR CANE IS PLANTED AND HARVESTED

In planting cane on great plantations, the fields are first plowed; then wide furrows, about seven feet apart, are made. Into these furrows are laid long, freshly cut pieces of sugar cane, three abreast. These are covered and soon sprout from the joints, just as potatoes sprout from the eyes. It takes a year for a cane crop to mature. When grown it is higher than a man's head and so thickly interlaced that one can scarcely make his way through it. When it is large enough, men and women with long knives cut the stalks close to the ground, it being well known that the most sugar is found nearest the root. This done, the leaves and tops are taken off and the stalks tossed in heaps which are collected and carried to the train in carts. Often the cane travels many miles before it reaches the mills. The stumps left on the plantation will usually, in course of time, sprout into two and sometimes three crops called "rattoon" crops. In Cuba, these continue to come up for from fifteen to twenty years, although planting is usually done once in three to five years. In Louisiana, however, rattoon crops cannot grow on account of frost, so planting is done every year.

When the sugar cane reaches the mill it is first squeezed between large, heavy rollers with a rough surface like a grater. Again and again it is crushed, until it comes out so dry that it can be used as fuel in the furnaces of the factory.

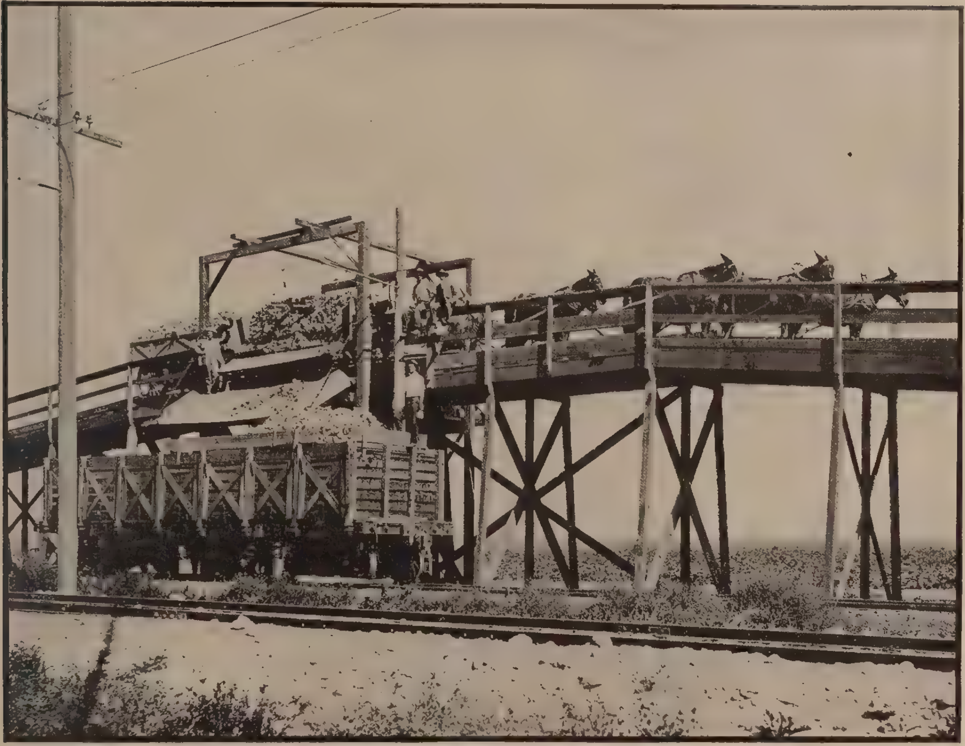
The juice, which runs out into troughs, is not at all tempting either to look at or to taste; it is sickishly sweet and looks like dishwater. How wonderful it is that from this thin gray liquid should come such pure white crystals! Of course, the liquid does not stay thin and gray long. It is poured into great tanks where, by means of sulphur gas, it is made to boil up into foam. Into the scum that collects on the top of this foam rise all the impurities; these are promptly skimmed off. Many times the juice is skimmed. It is then settled by putting lime into the liquid. Afterward it is ready to be boiled into sirup in great copper vats heated by coils of steam. These vats are connected in such a way that the juice can flow from one to another; as it travels along it constantly becomes clearer and thicker until the mass of grains look in it somewhat like brown corn-meal. When it reaches this stage it is drawn from the vats and run into metal cylinders or centrifugal machines which revolve swiftly. These cylinders strain off through their gauze covering a thick brown sirup which, if boiled down, can be made into second or third grade molasses. The best molasses, however, is made from the cane direct, and is known as New Orleans or Porto Rico molasses; it is not necessarily made in those places. While the sticky juice is being forced through the gauze by the rapid whirling of the cylinders, fine crystals collect on the inside of the gauze. At first these crystals are brown, but soon they pale and if they have been put in hot enough gradually become as light as a light straw color.

THE FACTORY BEET OF TO-DAY



TOP: BEET FIELD READY FOR THE HARVEST. THIS FIELD YIELDED TWENTY TONS TO THE ACRE. BOTTOM: "BLOCKING" AND "THINNING." THE MEN IN THE FOREGROUND ARE "BLOCKING" THE BEETS, LEAVING A BUNCH OF THEM EVERY EIGHT INCHES. THOSE IN THE REAR ARE "THINNING," OR PULLING UP SUPERFLUOUS YOUNG BEETS, LEAVING ONE IN EACH PLACE, EIGHT INCHES APART

Beet sugar photos are reproduced by courtesy of Truman G. Palmer.



A BEET-RECEIVING STATION

Such is the process of producing so-called "raw sugar" from the sugar cane as it has been described to us by one of the leading sugar growers, and as it is practiced on many plantations and in many mills. But in this inventive age no process of production is carried on long without changes and improvements. New machinery has been installed in many establishments by which evaporation is made to play a larger part in the process. In all our sugar-raising countries — in Cuba, Porto Rico, and Java, in Brazil, Peru, the West Indies, Queensland, Argentina, and the Philippines — the sugar cane is being cultivated on huge plantations, and the sugar mills are busy with the processes of extracting the juice and crystallizing the product. In the refinery the "raw sugar" must go through many more complicated processes. It must be washed and melted; the insoluble impurities must be eliminated; it must be filtered, crystallized, dried, and sorted, before there will emerge the granulated sugar of our most common use or the confectioners', loaf, or other special sugars.

BEET SUGAR — THE SUGAR OF THE TEMPERATE ZONES

Sugar cane flourishes only in tropical or semi-tropical regions. Sugar may be profitably extracted also from the sugar beet, which is not a tropical product, but can be and is cultivated in vast stretches of our own country, — as in Colorado, Michigan, California, Oregon, Utah, Nebraska, and Wisconsin, — and in Germany, France, Belgium, Austria, Poland, and Russia.

The demand of the civilized world for sugar makes it one of the most interesting of our industrial products. Any one who lived through the period of the Great War came to a realizing sense of its importance, and of the deprivation which every class of society suffers in its temporary and partial withdrawal from the market. Sugar is a most important article of diet to the northerly countries of the world; yet it has been produced in large measure in the southerly regions. Out of the fact of this interchange grow the monopolies, the speculations in sugar crops, and the shortages which are so carefully watched in financial and government circles. For this reason increasing interest attaches to the sugar beet, as a source of sugar supply which can be produced in the more immediate neighborhood of its consumption.

It was in 1747 that a chemist announced that the sugar beet contained the same kind of sugar as the sugar cane. Napoleon gave a stimulus to the industry by offering in 1806 a bounty of a million francs for the satisfactory production of sugar from home-grown plants. The farmers of Europe took up the industry much more rapidly than did those of the United States, but the sugar beet is being grown more and more in our own country.

The sugar beet is usually white and is not unlike the common garden beet. It is planted from seed. When the beets come up they must be thinned so that each one may have plenty of room for its leaves, for it is these leaves that are the sugar factories of the plant. Here, by means of sap and sunshine, the sugar is made. It is then stored away in the root of the beet. When the crop is ready for harvesting, the beets are pulled up and floated in canals to the washing machines, where they are thoroughly cleaned by means of revolving brushes. They are then cut into thin, V-shaped pieces called "cossettes." The cossettes are put into tanks of warm water, and as they bob about the sugar in them goes out into the water, coloring it black, like ink. This is no more inviting than was the murky, gray cane-sap. It is, however, purified in tanks until, by the aid of lime and acids, it comes out clear as water. The remainder of the process — the boiling into sirup and the crystallizing — is in general the same as is followed in making cane sugar, except that it is much more complete. The impurities of beet sugar are entirely removed in the centrifugal machines, and the product, when dry, is white granulated sugar.

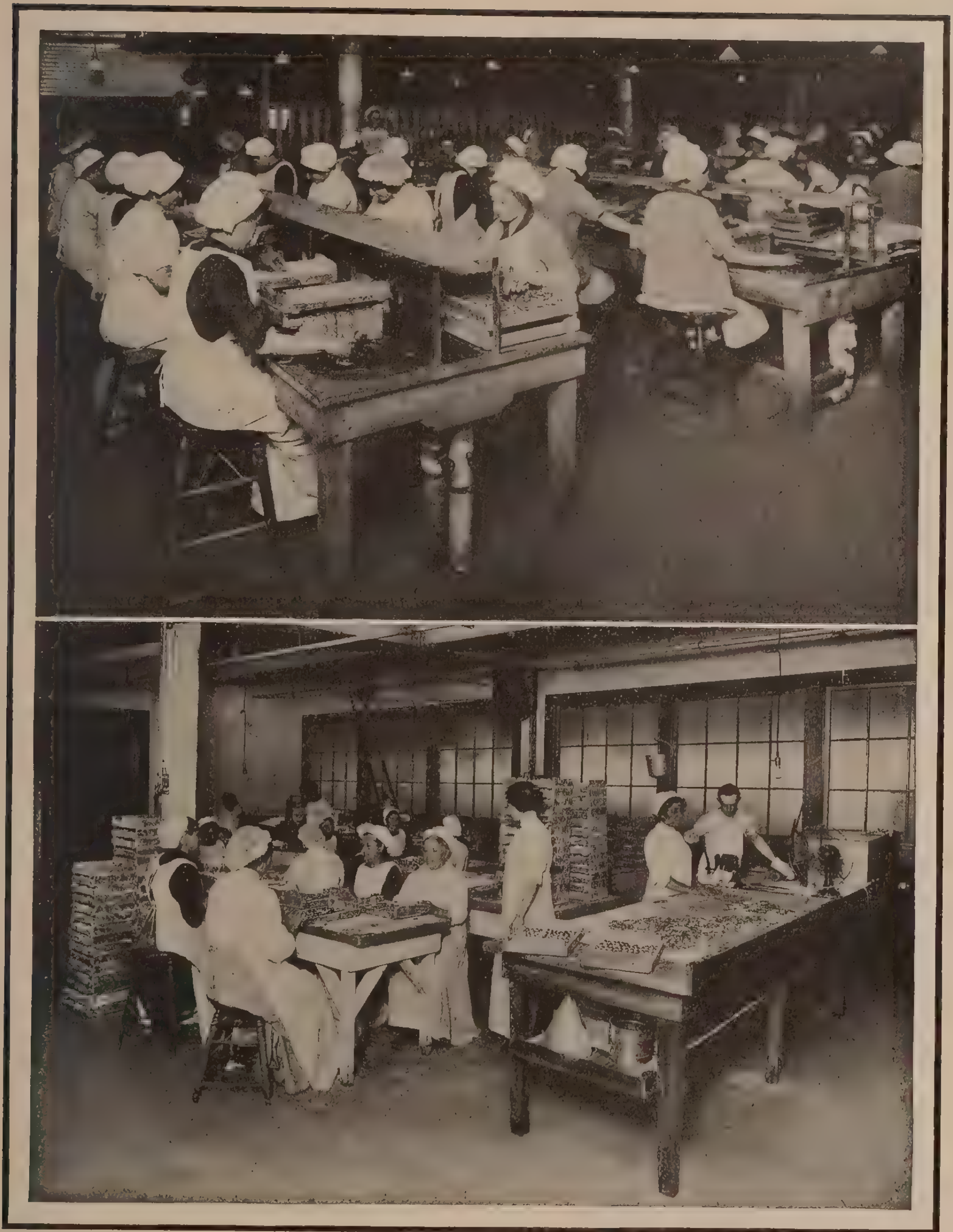
THE ANNUAL OUTPUT

When we talk of sugar we are talking in terms of an immense annual crop. Before the war the cane and the beet were each producing about nine million tons. Cuba produced in a recent year four million tons for export, Porto Rico more than four hundred thousand tons. The United States produced a million tons of beet sugar in a recent year, while in the same year the cane fields of the South supplied two hundred thousand tons. A great many people of many nationalities and kinds, from the dark-skinned laborer of a tropical plantation to the expert chemist of the refinery, are engaged in this industry of supplying the sugar for the world.

CANDY MAKING AS AN ART AND INDUSTRY

A GOODLY proportion of the annual sugar crop goes into the hands of the commercial candy makers, who add nuts and fruits, flavoring extracts and coloring matter, and turn out the attractive candies which tempt Americans into being the candy eaters of the world. Hundreds of tons of candy are said to be consumed in the United States daily; hundreds of thousands of workers are employed in the manufacture of confectionery. Although machinery plays so large a part in this business, still many hand processes are retained in the production of the most expensive candies, many of which are also made in comparatively small quantities instead of in huge "batches," because it is said that the most perfect flavor can be retained only in the smaller lots. In general it would seem to have been the distinction of the American candy maker that he has managed even in quantity production to retain the charm of the small confectioner. Nowhere else in the world is candy so delicious and yet so reasonable in price.

The method of making candy in large quantities is not so very different from the way we make it in our own kitchen. In factories the sugar is mixed with water and after being dis-



TOP: A CORNER OF THE GREAT ROOM WHERE THE CHOCOLATES ARE "DIPPED." WITH HER LEFT HAND THE GIRL TOSSES A CREAM CENTER INTO THE HOT MELTED CHOCOLATE, "DIPS" IT SKILLFULLY WITH HER RIGHT, AND DEPOSITS IT IN THE TRAY IN FRONT OF HER. BOTTOM: THE HARD CANDY ROOM. THE MAN AT THE RIGHT IS CUTTING "FLAKES" OF CANDY BY MACHINERY. THE WOMEN AT THE TABLE ARE STUFFING RAISINS

TOP: THE BONBON ROOM. EACH GIRL IS SITTING BEFORE A KETTLE OF STEAMING HOT CREAM, FROM WHICH SHE DIPS AND FORMS THE BONBONS. BOTTOM: A SECTION OF THE PACKING ROOM, WHERE DELICIOUS CANDIES ARE PLACED IN FANCY BOXES, AND THESE IN TURN TIED WITH RIBBONS

The six pictures here reproduced were taken especially for this book at the manufactory of the Apollo Chocolates.

solved in enormous kettles is boiled down to sirup. All impurities rising on this sirup are carefully skimmed off as it boils, and a watch is kept that the mixture does not boil an instant too long and return to sugar crystals instead of remaining a thick liquid. The rich sirup left after the boiling is known as "stock sirup" and forms the foundation of the various kinds of candy manufactured.

In order that an even heat may be maintained large candy factories use gas burners under their kettles instead of wood or coal fires. There is, too, a brass candy thermometer that tells exactly the temperature when the sirup will "pearl" or "thread," and when it can be made into soft balls, hard balls, hard cracked candy, or caramels. Instead of running to but 120 degrees, as do most thermometers, the candy thermometer has 400 degrees, and by consulting it the candy maker can see at a glance that at 220 degrees his sirup will "pearl," at 235 degrees "thread," and so on. Therefore instead of constantly testing the sirup in a glass of cold water the manufacturer knows instantly how long to cook his sirup. He cannot risk spoiling such large quantities. Sugar is too expensive to be experimented with. He has simply to decide what sort of thing he wishes to make and then apply his tests. *Caramel*, or 380 degrees, is the highest mark on his thermometer. If the sirup is allowed to boil beyond this point it is ruined.

In addition to the gas kettles and thermometer, the candy maker needs a large marble slab, cool and easily washed, for cooling, molding, and cutting his candy. He uses a flat wooden spoon, not unlike a paper cutter, while working, and he also has trays of various sizes and shapes. Another convenience always at hand is a set of metal bars used for marking off soft candies when partially cool. For molding peppermints and confections of similar shape, tiny rings called "cream rings" are used.

Until the pure food laws were enacted colored candies were regarded by many careful persons with disfavor. At the present time most of the dyes used are vegetable coloring and quite harmless. A preparation of spinach is responsible for the green candies; beet juice gives the red and pink tints; and saffron tones the bonbons to golden shades.

It has been said that we owe our start in commercial candy making to a French nobleman, the Count of Singeron. Exiled from France at the time of the Revolution, he fled to New York, where he took up the occupation of frosting and decorating cakes and making the bonbons for which France was famous. Switzerland gave us the chocolate bar and the nougat, Turkey the fruit paste. Americans have taken all these kinds and made them their own, producing in enormous quantities candy of a high quality.

FRUIT

THE raising of fruit is one of the great industries of the world. And what is fruit? Have we ever asked ourselves the question? Fruit is that product of a plant, bush, or tree which contains the seeds. It is created solely for this purpose, and together with the plant and its blossoms lives only for this end. Some of the things we call vegetables, such as squashes, cucumbers, tomatoes, and peas, are in reality fruits. It is because of the salts they contain that fruit and vegetables are necessary to our well-being. Our bodies have in them many of these salts, which are continually passing off and which must all the time be replenished in order that we may be kept in good health. Since the beginning of the world these fruits have grown wild, and it has taken many centuries for man to learn which ones were useful as food, and how to cultivate them. The many delicious varieties we now have are the result of much patient labor and experiment.

Under three general heads most fruits may be classified:

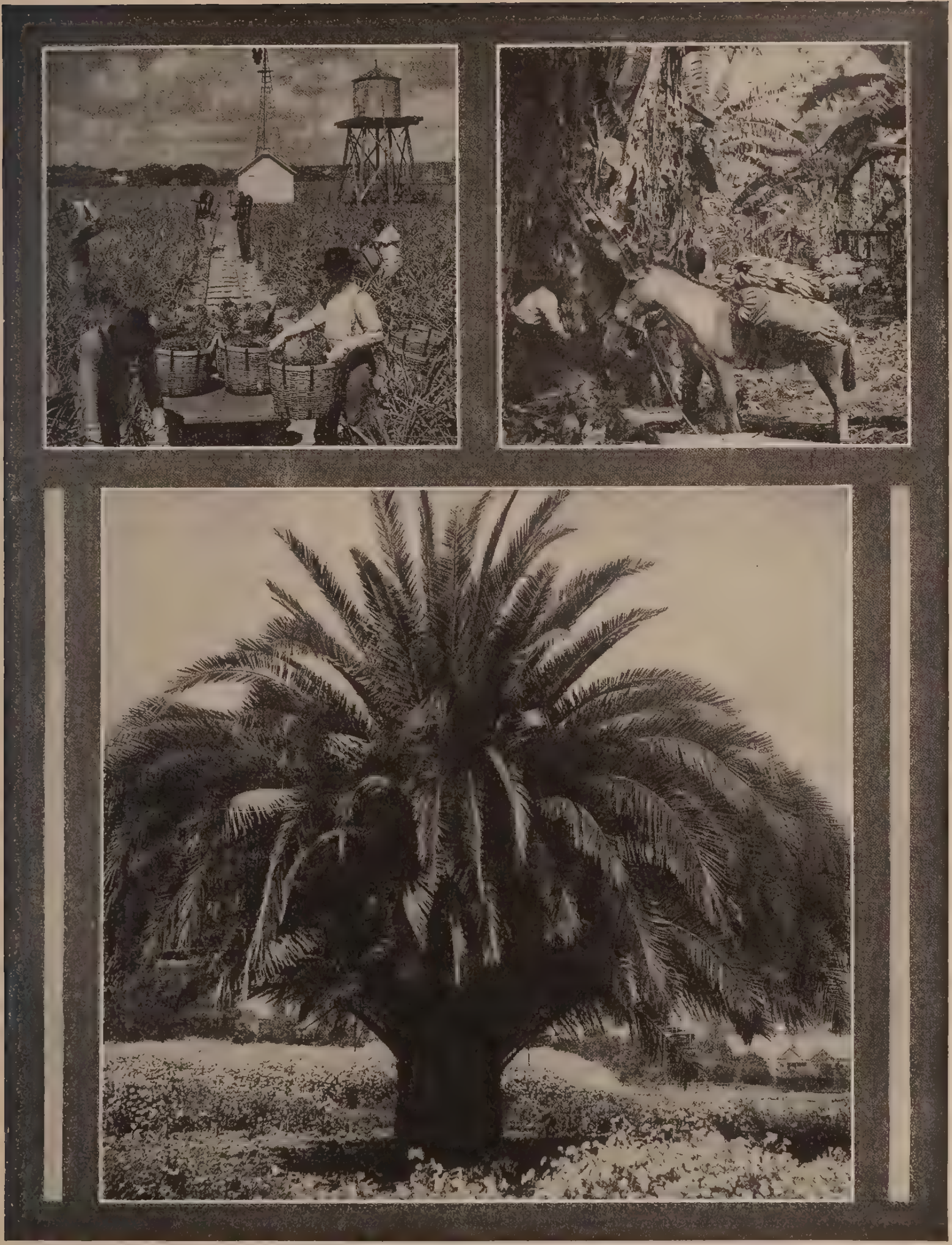
- Orchard or Tree Fruits:
  - Pome fruits — apples, pears, etc.
  - Drupe fruits — peaches, plums, cherries, etc.
  - Citrus fruits — oranges, lemons, etc.
  - Nuts — fruit with hard shells.
- Vine fruits — principally the grape.
- Small fruits — berries of all kinds.

HOMES OF THE VARIOUS FRUITS

The United States is remarkably rich in fruits. With the exception of a few kinds, we

Courtesy Royal Mail Steam Packet Co.

A BUMPER CROP OF MANGOES, JAMAICA



TOP: LEFT, HARVESTING INDIAN RIVER PINEAPPLES, FLORIDA. RIGHT, BANANA HARVESTING, COSTA RICA.
BOTTOM: DATE PALM, PASADENA, CALIFORNIA

raise in great quantities every sort which we require. The Mediterranean country also produces a vast supply — oranges, figs, olives, and grapes growing in abundance under the hot southern sun; there are, however, many of our American fruits which do not thrive there. England excels in raising strawberries and gooseberries of wonderful flavor and size, but other fruits require so much cultivation there that only comparatively small quantities can be sent to the markets. France, like Italy and Spain, is famous for its vineyards, and there was a day when we depended upon these countries for most of our grapes; now, however, California supplies us with these as well as a great part of our raisins.

Such vast numbers of apples do we at the present time receive from Oregon and California that it does not now pay to pick and transport the crops from our small Eastern farms; Western apples are grown and shipped on such a large scale that they can be marketed in the East cheaper than our own farmers can afford to sell them. This fact has greatly discouraged our New England farmers, who now simply gather what they need for their own use and often leave the rest of their crop to fall or rot on the ground. As the apple is essentially a fruit of the Western Hemisphere, many barrels are each year shipped from Canada and the United States to England and other foreign countries.

Oranges also come from California, where they are less liable to be injured by sudden frosts than are the Florida crops. We receive, too, a great many of them from Cuba, Porto Rico, Jamaica, and the West Indies, and cases of smaller ones from Italy and Spain. Grape fruit is grown successfully both in California and Florida. Lemons, on the other hand, we must buy from Sicily and southern Italy, since the output from California and the West Indies is not sufficient for our needs.

For bananas we must rely, too, upon other countries, but as we can get them very cheaply from Cuba, Central America, Yucatan, Costa Rica, and the West Indies, they lie near our own doors. In these southern countries they are grown in immense quantities and serve often as a food rather than as a luxury. Despite many experiments, we have never been able to raise bananas in California. We do, though, raise figs there, and we also get them from Florida and the Mediterranean countries. Our own figs are far more carefully washed and packed than are the figs from countries where the pure food laws are less strict.

Peaches we have, again, from the Pacific coast, and also from Delaware, Georgia, and Michigan. In the South it is now becoming so much more profitable to raise cotton, however, that recently several great peach orchards were destroyed to give place to cotton fields. The peach as well as the pear tree came originally from the Orient. The pear used to be one of our New England products, but most pears come now from the Western fruit-growing centers.

Florida and California rival each other in the cultivation of pineapples, and many of these are grown too in Mexico, the Hawaiian Islands, and in the hot countries encircling the Caribbean Sea.

Dates we must beg from Egypt and parts of Africa, where mighty palms, some of them a century old, still yield rich crops. Like the banana, the date is known among orientals as a food.

HOW WE STORE FRUITS AWAY

With all this abundance of fruit at hand there is, of course, far more than we can use at the time it ripens. In consequence much of it is canned, that it may be kept for us until we need it. Some of this preserving is done in our homes, and you have no doubt smelled the tempting fumes of boiling sirup, and have perhaps lent a hand in coring or paring the fruit before it is dropped into the hot melted sugar.

At factories this canning is done on a very extensive scale, and the fruit is sealed in tins or in glass jars to be sold to the apartment dweller, or to the housekeeper who is too indolent or too busy to do her own preserving. The industry has developed until it has become almost an art. Not only are fruits sealed away, but all sorts of vegetables are also preserved for winter use. Each year sees the business more hygienically and perfectly conducted, and so cheap have such products become that often it is far less expensive for the housekeeper to buy them than to attempt canning for herself.

When fruit and vegetables are to be kept for but a short time they can be put in cold storage, where the low temperature of an ice-chilled room will prevent them from spoiling. This is the way such products are kept on shipboard and in large hotels.

* * *

SALT

SALT is such a common and necessary product that it is used by everyone. You know how tasteless food is if there is not enough salt put in to flavor it. Perhaps the best definition of it is that of the schoolboy's composition: "Salt is what makes potatoes taste bad when you don't put any on." Very likely we do not realize that no living thing can exist without a certain number of these simple white crystals being carried into the system and into the blood. Animals are quite as dependent on salt as is man, and doubtless you have seen farmers giving it to their cattle and sheep. Shepherds often call their scattered flocks together by making a sound which the creatures have come to understand means *salt;* the sheep themselves, too, give a peculiar call to summon each other when they find this substance in the soil of their pastures. Centuries ago one method of torturing criminals was to put no salt in their food and give them nothing but flat rain water to drink. Under this treatment they soon died.

And yet it is a curious fact that while a certain amount of salt is necessary to all life, too much of it is fatal. Nothing can grow where there is an abundance of salt; and this is the reason why salt is used to preserve meat, fish, and other kinds of food. No germs can thrive when products are packed in it. Fishermen who go on long cruises always carry with them a supply of salt, and as fast as they catch their fish they clean them and salt them down for market.

WHAT IS SALT AND WHERE DO WE GET IT?

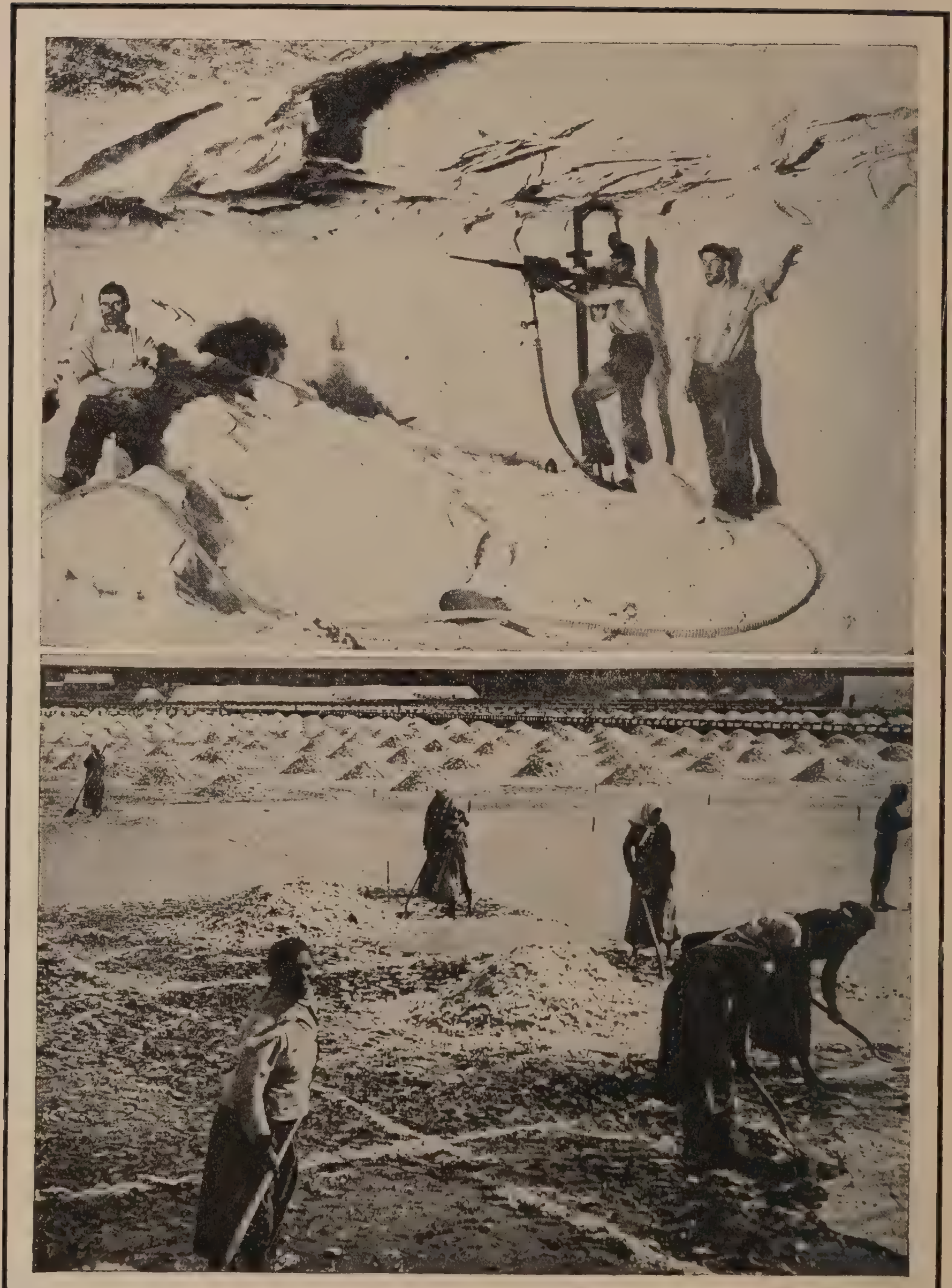
Everywhere about us in the world there are two elements: sodium and chlorine. The soft metal so easily cut with a knife, and which so quickly becomes impure, is sodium; chlorine is a dangerous gas which kills when much of it is taken into the lungs. When the atoms of these two substances blend we have as a result sodium chloride or common salt. This blending is constantly going on; it takes place in the soil and in the water. In consequence the sea is full of salt, and by this means the vast expanse of water is kept from becoming foul. Great deposits are also found in the earth, solid masses of salt often covering tremendous areas; we also find salt welling up in the form of salt springs.

Thus, you see, we have three ways of getting salt.

First, we may evaporate sea water in the sun and thus extract the salt from it. Probably this was the earliest method of making salt. There is, however, such a small percentage of salt in such water that this is a very slow means. The sea water is either pumped into tanks and left to dry out, or it is sometimes boiled down and passes off in the form of steam, leaving the salt behind it. In Southern Europe and in Asia salt is still made in this primitive fashion.

The second way is to get salt from salt springs, where the percentage of salt is more than ten times as great as in sea water. The brine from these wells or springs is pumped into tanks and either left to evaporate in the sun and air, or it is boiled off in big pans. If table salt is desired the salt must be taken from the tanks or pans while the crystals are small and fine. Coarse salt is left until it forms in larger grains. Fine salt is baked in order that it may be thoroughly dried, and often some other substance, such as starch, is put with it to prevent it from caking and becoming damp. In Russia there are very extensive salt springs where quantities of salt are annually evaporated. In the United States the largest salt springs are at Syracuse, New York, and at Warsaw, Michigan.

The third way to get salt is from mines. The largest salt mines in the world are at Slanic, Roumania, where down three hundred and forty feet below ground there is a little



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TOP: IN A SALT MINE IN LOUISIANA. BOTTOM: A RESERVOIR AFTER EVAPORATION; TURNING UP SALT

MILKING TIME ON AN UP-TO-DATE DAIRY FARM

city in which hundreds of men work, annually getting out thousands of tons of salt. There are famous mines, too, at Wielicza, where there are rooms and rooms underground, all with walls and ceilings of solid salt; England has large salt mines at Norwich, Cheshire, and in many other places. In our own country much salt comes from the Colorado Desert. Ages ago this great waste was covered by the ocean, as were probably many other parts of the world where salt is now found.

The several kinds of salt include rock salt, made from large crystals, which is used for packing fish and meats, and is sometimes sprinkled upon our catch basins to prevent them from freezing; solar salt is that made by dissolving sea water in the sun; common fine salt is for table use; common coarse salt is used for cooking; and dairy salt is necessary for the making of butter and cheese.

There are many interesting stories about how the Roman soldiers received their pay in salt or *salarium*, from which term our present word "salary" is derived. In France one of the causes of the French Revolution was the tax on salt; everyone was compelled to buy each year of the government a specified amount of salt, and it was against the law for anyone to get it in any other way. As the price demanded by the Crown was very high the people rebelled, as justly they might. There are many other stories of the part salt has played in history. Perhaps if we read them we should more fully appreciate the value of this common household article which it is now so easy for us to get.

DAIRYING

HAVE you ever thought that, next to bread and water, milk is used more commonly than any other article of food or drink? To supply our great American cities and towns with milk there must be within easy reach one cow for about every twelve persons! And

Photo, Ewing Galloway, N. Y.

GETTING MILK FROM THE FARMER FOR CITY USE

Since it is reckoned that there must be a cow within easy reach of every twelve persons in a city, the motor truck is of great service in getting a fresh supply when we remember that the average person eats bread and butter three times a day, we need not feel surprised that dairying has become a large and profitable American industry.

Milk easily becomes tainted, as germs multiply in it very rapidly. Impure and diseased milk is a serious danger to health, especially to that of infants, whose food, as we know, consists solely of milk. For these reasons, state and city boards of health keep the public milk supply under close inspection, that it may be pure and wholesome.

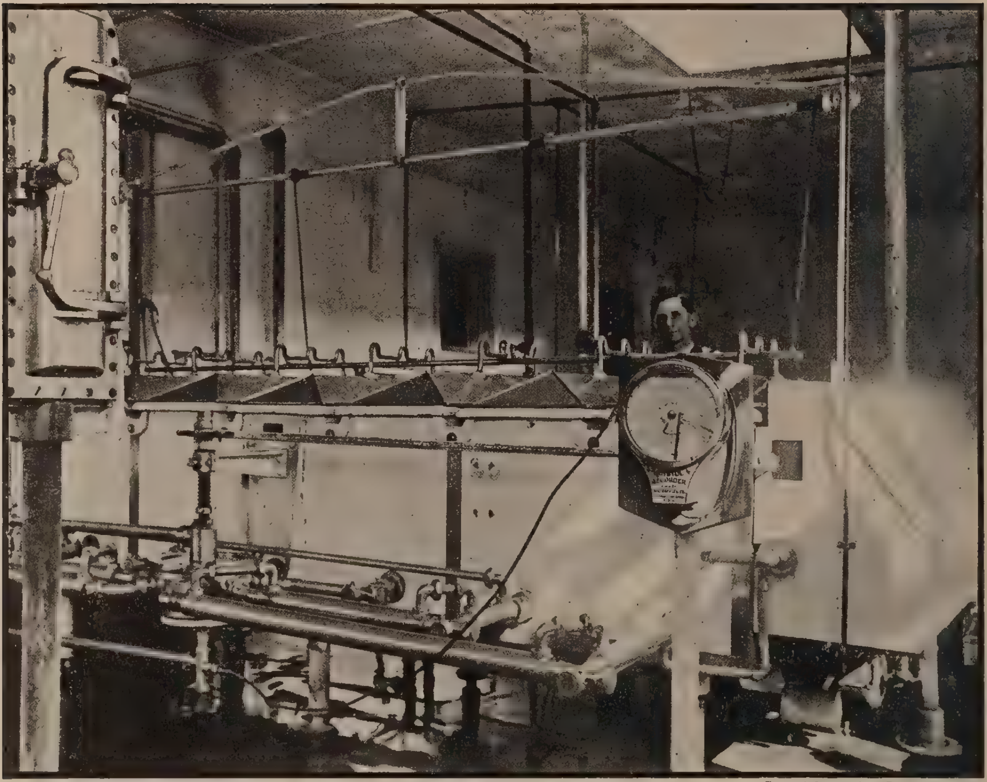
But pure and wholesome milk can be produced only in clean and sanitary dairies. In a modern, well-kept dairy the cows are housed in large, airy, well-ventilated buildings of concrete or wood. These and all other dairy buildings are kept scrupulously clean, as are all dairy utensils. The greatest care is taken of the cows that they may be clean, healthy, well-fed animals. The milkers must also be perfectly clean in all respects, and are not allowed to use tobacco.

As soon as the milk is drawn, it is removed to a clean, dry room and strained through a metal gauze and a flannel cloth or layer of cotton. It is then aired and cooled, and is ready for the market. If it is stored, it is held in tanks of fresh, cold water in a dry, cold room.

A large amount of the milk that is produced must be turned into butter. Butter is made from cream, the cream being first removed from the milk by a machine called a "separator," which turns the milk at from 5,000 to 9,000 times a minute. The cream is now ready to churn, if sweet cream butter is desired; otherwise it is kept awhile to "ripen" or sour, and then churned. The milk remaining over from the churning is called "buttermilk." This being drawn off, the butter is washed, and worked over, either by hand or a butter worker, and is salted and packed.

Another product of milk is cheese, made from the curd or fatty portion, which is thickened by a special process and cooked, the whey or watery part being drawn off. It is then ground, salted, pressed into solid form, and set away to be cured or "ripened."

A MODERN COW BARN



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A PASTEURIZING MACHINE

Showing the large tank in which the milk is heated, and (at the right) the automatic recording thermometer

As a national industry, dairying is one of our most progressive forms of agriculture. From the supplying of the right foods and the care of the cow to the shipping of the milk or butter or cheese to the consumer, every feature of the business has been made the subject of most careful tests, so that the farmer has the information and the implements supplied to make his product fit certain definite standards. By a simple method he can, for instance, test his milk for its fat-content, and be able to register it exactly before it leaves the farm. He can also pasteurize his milk himself.

Dairying is one of those industries which has expanded almost overnight from a highly local business to one with a fairly wide range of territory. The raising of cattle for milk, butter, and cheese is done chiefly in the northeastern and central regions. Yet here, with the new methods of cooling and the improvement in transportation, both by railroad and by motor truck, milk is daily carried increasingly long distances. Where the access to a city is possible, milk is usually sold as the chief product. In the communities of the central region of the country, the milk is more frequently turned into butter and cheese.

If it be true, as certain food experts claim, that certain national traits of ability and leadership go with the peoples who have practiced dairying and lived on butter, cheese, and milk, the United States should rank high, for we are said to consume more milk and butter than any nation in the world, though we are behind some of the nations of the Old World in our average use of cheese.

Official Photo, U. S. Army Air Service

WHEN A SMALL PHOSPHORUS BOMB, DROPPED FROM AN AIRPLANE, HITS A DISCARDED WARSHIP

INVENTION AND INDUSTRY

> "Into the dust of the making of man
> Spirit was breathed when his life began,
> Lifting him up from his low estate,
> With masterful passion, the wish to create."
>
> *Van Dyke.*

WITH these words our book began; with these words it might well end. The creative instinct implanted in man has been responsible for all the inventions and industries which have contributed to make up our modern world, as they have been sketched on these pages; it will be responsible for the developments along these lines in the future. Man's progress in the past, wonderful as it has been, is probably but a forecast of his progress in the years to come. It is only within the last twenty-five or fifty years that the great system of modern industry has been built up. Within the memory of our boys and girls, flying and talking through the air have been introduced as new elements of civilization. The creative instinct is never satisfied; it works in every generation to accomplish new wonders.

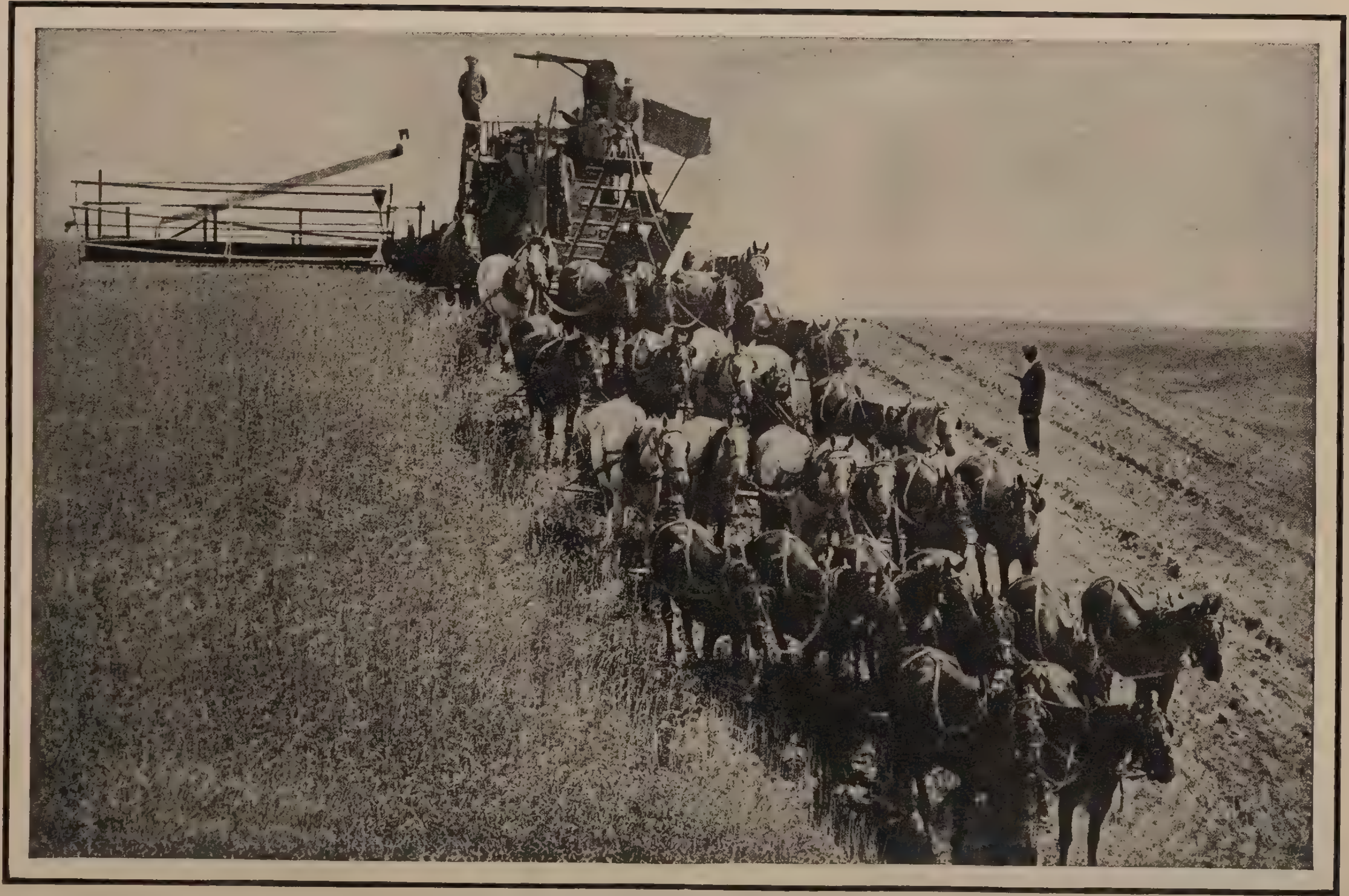
WHAT IS IT ALL ABOUT?

We have told the tale of inventions; we have followed the course of certain leading industries. We have touched again and again on the change that this new machine, this discovery, or this process has made in our daily life. Now let us pause to consider for a moment what is the goal towards which we are traveling. The creative spirit in man is working, but towards what ends? Are the scientists in their laboratories and the armies of workers in the factories all guided, however indirectly, by one ruling principle and towards one main objective? When we think back over the varied stories of this volume, we shall find that there is such a ruling principle which runs through every chapter, and that principle is that man has set out to conquer the world. In all his undertakings he is fulfilling the ancient command of the Garden of Eden to subdue the earth and to have dominion over it. As we think over the inventions and accomplishments of the past fifty or one hundred years, we shall see how rapid has been his recent progress, and how great is the promise of the next century or half-century.

If we were to sum up the three things that man desires most, beyond the bare necessities of daily life, they would seem to fall into three main groups, — to become more independent of space, to become more independent of time, and to relieve himself of heavy bodily labor. The more gain he makes in any one of these directions, the freer is his life in this world in which he finds himself. Let us, therefore, trace out our inventions and industries with these ideas in mind.

HOW MAN IS SAVING HIMSELF HEAVY LABOR

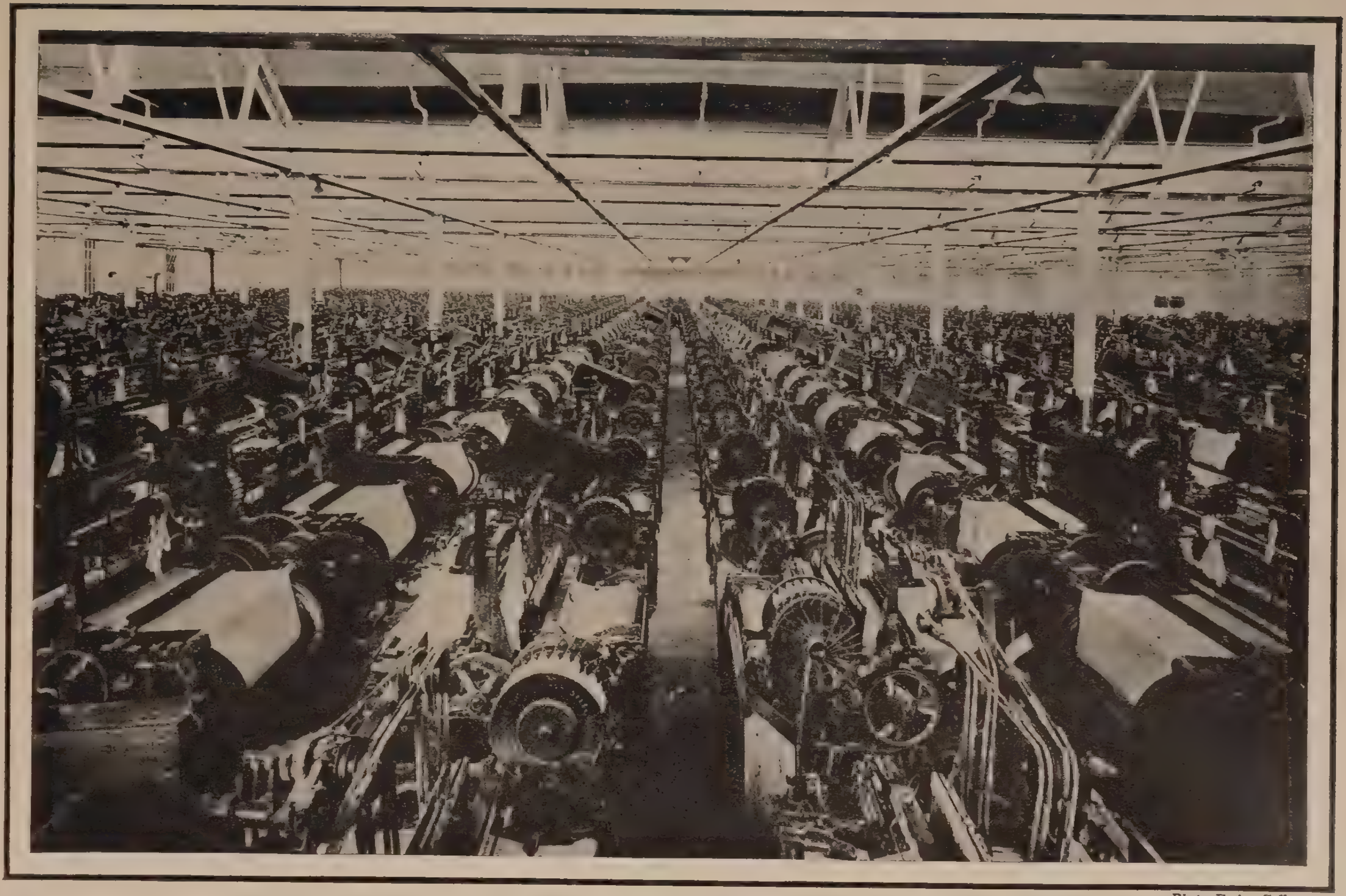
Labor-saving began with the introduction of machinery. The moment that inanimate objects fashioned from wood or iron can be made



Photo, Ewing Galloway

HORSE POWER RAISED TO THE THIRTY-THIRD DEGREE

A "header" cutting and threshing wheat in Washington State.



Photo, Ewing Galloway

POWER FROM MACHINERY

Contrast with the scene on the opposite page, the potential power concentrated in this vast weaving room in a textile mill.

Photo, Ewing Galloway

BLASTING AWAY A MOUNTAIN

This snapshot was taken a small fraction of a second after the charge of dynamite planted deep in the side of the mountain had been touched off.

by the introduction of some source of energy to do work for man, that moment he is relieved from the necessity of making his own bodily machine supply all the energy and all the mechanical adjustments for doing the work he wants done. Man's first method, and one which he still uses to a large extent, was to provide machinery for which animals could supply the driving force. His unit of measure was for such a long period the power that one horse could supply that even to-day the working capacity of an engine is often reckoned in its "horse power." Yet how limited is the range of a machine depending on horse power compared with that of one driven by some fuel-using machine! In our photograph taken on the wheat fields we have a striking example of horse power, raised in this instance to the thirty-third degree, but, splendid as that team of horses is, how bulky and difficult of direction it is compared to the weaving machines gathered under one roof in the picture that faces it! In that single room with its machines stretching away into the distant corners we get a symbol of potential energy as it is doing man's work in the modern world of machinery.

A FUEL-USING AGE

For the running of his engines man is depending chiefly on the fuel which he finds stored in the earth. We have followed the story of the steam engine, with its contribution towards doing the work of the world. The steam engine is adapted to the use of a fuel like coal; it would seem as though it would be used so long as the supply of such fuel continues. But the steam engine could never have been utilized for such machines as an automobile or an airplane. One can hardly picture an aviator carrying along the contents of a coal bin or an automobilist as having at the rear of his machine a fireman or stoker to replenish his fire. Here oil enters as an available fuel and makes possible the internal-combustion engine, described so fully and clearly in an earlier chapter.

Man's work, then, is being done in large measure by the heat of combustion, or, in simpler language, by burning. And what is combustion or what is fire? From the chemist's point of view it is caused by the union of two elements, — by the union of carbon and oxygen, or hydrogen and oxygen. The oxygen is in the air, and therefore easily accessible and manageable. Carbon is stored away in the earth in the form of coal; but it is a solid. It must be dug up from the earth, transported, and

Photo, Ewing Galloway

ACETYLENE WELDING OF STEEL

By the concentration of intense heat at a single spot, this workman can accomplish easily what no man-power unaided could achieve.

shoveled into the firepot. Petroleum is likewise stored in the earth; it is a fluid. It is imprisoned under such heavy pressure that it is ready to gush forth when an opening affords the least chance; it is easy to transport; and it will flow into an engine under some system of automatic control. Crude petroleum would not be suitable for the internal-combustion engine, but gasoline, distilled from petroleum, does provide the ideal fuel-fluid, having a combination of hydrogen and carbon, which puts it in the class of "hydrocarbons," giving good heating results, being clean and easy to handle, and being easily converted from its liquid state into a gas for combustion. The use of fuel for power in steam and internal-combustion engines has been at the basis of our modern machine-driven civilization.

ELECTRICITY AND CIVILIZATION

From the mechanical point of view the great call of the world is for energy which shall keep things going. If you turn to Volume XI, you will read in the opening chapters how all life depends on and utilizes the energy from the sun. Our whole world is run by energy supplied from that distant but all-important central body about which the earth takes its course. If we are in danger of becoming boastful over man's machines, the story of energy as utilized by Nature in her living machines will make us duly humble concerning man's small successes in acquiring and applying the sun's energy as it pours in on the earth. "The work of the world," it has been concisely said, "is done by sun power. Whether it be accomplished by the muscular labor of horses or human beings, by the whirling of windmills or water wheels, by the burning of wood, coal, or oil, or by the swift and silent electric current, the energy comes directly or indirectly from the solar reservoir."

This energy we can neither make nor create. We can only use what we find in the world about us. One big source is in our fuel supplies, which furnish chemical energy by combustion; the other is in the waterfall, which furnishes hydraulic or mechanical energy. Fuel we can transport; water power we could not transport. "It was the electrical engineer who made the water powers of use," writes Steinmetz, "by changing, 'transforming' the hydraulic energy of the waterfall into electric energy, to send it over the electric transmission line to the distant places where energy is needed, and distribute it as electric energy. . . . It is the characteristic of electric energy that it can be distributed and converted into any other form of energy in a very simple and highly efficient manner, and that the economy of distribution and conversion is practically the same, whether we want the minute amount of energy to ring our doorbell, or the power of hundred-thousands of horses to drive the propellers of the battle cruiser. . . . Electric energy thus is the form of energy best suited for the transmission and supply of the world's demand for energy."

Electric energy is unique in this particular. It is all produced by conversion from some other form of energy. There is always a generator, producing mechanical energy, as from water power, or a battery, producing chemical energy. But as we have seen in our story of "Electricity" in an earlier chapter, and as we shall see in the story of the use of water power in the record of "Man's Achievement" in Volume IV, it is useful beyond measure as an intermediary for the transmission and ready delivery of energy for our instant and efficient use.

Electricity is man's newest servant in the march of civilization. In saving him labor by doing his work for him, and by extending his powers, its present use is enormous, and its service in the near future is incalculable.

MAN'S GROWING CONTROL OVER SPACE AND TIME

In an essay on the automobile Maeterlinck says, "Space and Time, its invisible brother, are perhaps the two great enemies of mankind. Could we conquer these, we should be as the gods." Our machinery has done much towards giving man this conquest. Run through the inventions as they have been listed and see how they conquer space, and therefore time: the steam engine, and with it the development of railroads and of steamboats for ocean travel; the internal-combustion engine, and with it the automobile, the farming machinery which enables man to extend his cultivation of the land, the motor boat, and the airship; the electric battery or generator, and with it the telegraph, the telephone, and the radio system, — all these have brought man within the last fifty years into a most remarkable independence of the limitations of space. Even the Arctic explorer reports his adventures back to the civilized world by radio, and a President of the Unites States may sit in the White House and talk to an audience comprising the whole United States, with the possibility of a fringe of hearers "listening in" from other lands.

Commerce is the handmaid of intercommunication. Man is a born trader. If he talks with anybody, he will exchange products with them. So our industries reflect to an amazing degree this independence of space. A writer in the *North American Review* has well illustrated the manner in which we touch the ends of the earth in even so simple, as it would seem, a process as the manufacture of a pair of shoes: "The welt is cemented to the sole with a mixture of asphalt, probably from Venezuela, and rubber, from Brazil or the Straits. The upper is sewed to the welt with linen thread made from flax grown in Russia or the Argentine and spun in Ireland or Scotland. The fancy stitching in the upper is of silk from China or Japan. The soft tops of high shoes are made usually of goatskins produced probably in India or China or South America. The tongue in high-grade shoes is likely to be Australian kangaroo skin. The metal eyelets for the laces are made of a composition of nickel from Canada, tin from Malaya or Bolivia, and

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EDISON AND STEINMETZ

Two of America's foremost inventors comparing notes in a laboratory.

zinc from Missouri or Mexico." We have told tales of foodstuffs from afar, and in this connection we should not fail to recall the "Scientific Refrigeration" which has made possible the shipping of meats and fruits and vegetables. The pioneer farmer would consider the array of foods which we spread on our tables at all seasons of the year nothing short of miraculous. Kings did not fare so sumptuously in former days. It would seem as if perishable foods could be transported anywhere and kept in some form almost indefinitely. We sympathize with the man who threatened to write the romance of the tin can, that sealed container from which come forth at our touch such a variety of products.

Photography and printing have done much to obliterate time and space. The scene of a moment is caught by the camera and flashed to us so quickly that we can see within a few days or hours of the event kings crowned or volcanoes in eruption. The people and customs of other lands are made so familiar to us that we lose the sense of strangeness which is the barrier formed by distance. The printed word serves as does the telephone and the radio to do away with the limitations of both distance and the passage of time.

MATERIALS AND THEIR POSSIBILITIES

As we trace back the machines which work miracles in our daily life, we find that they were designed in the workshop of the inventor. As we study the industries, we learn that the scientific formulas for the combination of this substance with that were evolved in the laboratory of the scientist. It is well, therefore, to take a look into these places of quiet investigation and experiment. We shall find out how some of the achievements of the past have been accomplished and why new wonders are to be expected in the not far distant future.

Man's conquest of the world depends on his understanding of the materials out of which the world is made. If he can know how to handle inanimate things like wood and iron and the juice of the sugar cane and the milk from the rubber tree, he can gain a mastery over them which will make them serve his purposes. When we take the long look at things, we see man as a stranger put down in a world of wonderful, unknown materials, each of which he may test and test again to gain its secrets and know its possibilities. It is in the study of materials that man has made some of his most conspicuous recent progress.

THE CHEMIST AND HIS WORK

To the chemist the world is a world of ninety or a hundred elements appearing in various combinations and with various properties due to these combinations. He does not ignore the life principle which enters in, but his business is to deal with these elements as they appear. Because he thinks and talks of elements in atoms and molecules, too small for any one to see, and labels these tiny invisible portions with letters of the alphabet as shortcuts so that he need not keep repeating their names, the chemist's books and even his talk are likely to seem over-learned and technical for the ordinary person to follow. But lately he has taken a great deal of pains to explain his problems and his interests in terms simple enough for the rest of us to follow with appreciation.

The charm of the chemist's job lies in the fact that while one half of his concern is to take things apart to see of what they consist, the other half is to put things together in new and different combinations. He would express this to you in two words, — "analysis," the taking apart, and "synthesis," the putting together. When we were discussing rubber, we spoke of the fact that there was such a thing as "synthetic rubber," a product not of the tropical rubber tree but of the chemist's laboratory. Natural rubber when analyzed by the chemist proved to be made up of carbon and hydrogen in certain fixed proportions. Caoutchouc, or raw rubber, would be described by the chemist by the formula $C_{10}H_{16}$, which means a combination of ten carbon atoms and sixteen hydrogen atoms. Now there is a liquid known to chemists, called "isoprene," which has five carbon atoms and eight hydrogen atoms, its formula being C_5H_8. If the rubber was heated, this liquid was given off. The first step of the chemist's task, that of analysis, could be done quite simply; but, as in most cases, the second step, of synthesis, the turning of the liquid isoprene into the gummy rubber, was not so simple.

A method was finally found by which the isoprene could be dried over another substance, and there resulted what seemed, to all intents and purposes, real rubber. The chemist had accomplished his purpose: synthetic, or artificial, rubber had been created in a laboratory without the help of the living rubber tree. Next, the practical side of his discovery must be considered. Did the artificial product follow closely the same lines of behavior, when put to the same uses, as the natural product? In this particular case synthetic rubber seemed to meet most of the tests. Most important of all, did it prove that because artificial rubber could be produced in a laboratory on a small scale, it could be produced in a factory on a large scale more cheaply than by Nature's processes? Here is the test of every synthetic product, of every substitute offered for a natural product. The chemist's discovery must be tested by the measuring rod of expediency. Artificial rubber is being manufactured commercially; but the expense of getting the isoprene, which must in its turn be extracted from other substances, has kept this output from rivaling to any great extent the natural product. Still the chemist has made a valuable contribution, for we know that in the case of a shortage our nation could manufacture rubber, and a change in values or some new discovery may at any time make the synthetic rubber cheaper to produce.

Photo, Ewing Galloway

A CHEMICAL LABORATORY

Maintained in a meat packing plant.

THE ROMANCE OF COAL TAR

Chemists are always studying the by-products, the seeming waste products, of industrial processes. When coal was treated in gas works and in coke ovens to produce gas and coke, there came off in the process a black, sticky substance. This was regarded as waste and was gotten rid of, often with considerable bother. But chemists worked in their laboratories on this coal tar. One day an English chemist's assistant, William Henry Perkin, washing the glass tubes after an experiment that had failed, noticed that the black sticky stuff from his tubes kept coloring the water purple. Out of so simple an observation made by a lad in his 'teens came the entrance into the great field of dyes made from coal tar. From the refuse of the gas works was created a new industry. In the commercial list of dyestuffs published in a recent year there were a thousand dyes made from coal tar.

What this releasing of a rainbow of colors from a thick, oily black fluid means in our lives, it is hard to estimate. If the only dyes available were vegetable dyes, the materials and foodstuffs which we handle would necessarily be deprived of much of their color, for the supply would be very limited. As it is, the chemist can see to it that our clothes are tinted in a thousand hues, that our houses are painted to any shade we desire, and that our bottled and canned goods are harmlessly treated with coloring matter which makes them more attractive. All dyes do not come out of coal tar, but it is the source of an incredible number of the tints that make up the color scheme of our daily lives.

Photo, Ewing Galloway

PUMPKIN FIELD

Yielding good second crop after application of fertilizer to the soil.

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ARTIFICIAL LIGHTNING, MAN-MADE IN A LABORATORY

This photo shows a flash of 1,500,000 volts crossing a gap of 14 feet. In this flash a force is released, for the fraction of a second, of more than ten million horse power—that is, greater than the total electrical power of the country.

SOME PROBLEMS OF TO-DAY

To tell in any one year on what problems chemists are engaged is perhaps venturesome beyond justification; yet it would seem that there are certain lines on which the thoughts of scientists are concentrated. One is the evolving of substitutes for certain vegetable products. An immense amount of wood pulp is used each year to supply the cellulose or plant fiber which is the basis for our paper and for kindred articles. We are cutting down our forests at an alarming rate for this purpose. So there is much research under way for a substitute for wood pulp in the manufacture of paper. With the increasing use of rubber, there is constant study to improve and cheapen the process of making artificial rubber. Minerals are a subject of great interest through the possibility of making alloys, or combinations of one with another, which will serve better than those already in use to meet some of the new calls. Aluminum, for instance, because of its lightness is being tested out for airplanes, and because of its being non-inflammable and more durable is proving a useful substitute for cellulose in motion-picture films. There is constant search for a cheap and satisfactory motor fuel, which may come from any one of a dozen substances that contain the necessary chemicals in suitable proportions.

It is a tribute to the discoveries of the past that manufacturers are taking more and more interest in the research work of the chemist. Most of the great industrial plants now maintain research laboratories where new methods are constantly being tried out. One large chemical corporation offers a prize of twenty-five thousand dollars to the chemist residing in the United States who shall be adjudged to have contributed the most in a given year to the benefit of the science of chemistry and of the world. The United States Government maintains under its different departments an army of research workers engaged on problems of this type, and the great medical foundations are always active in such investigation. There has never been a time when the health of our industrial workers has been so carefully studied or their work watched so that accidents may be prevented by safety devices.

THE FARMER AND THE SCIENTIST

The farmer faces one of the most constant and definite of chemical problems. Growing plants take certain substances from the soil. The soil must have these ingredients fed back into it if subsequent crops of plants are to find the needed food. The farmer of olden times used to apply manure to his fields and to plough in certain crops, knowing that it improved his future crops but without much idea of the reason. Now he knows that these were successful fertilizers because they supplied certain needed substances, notably nitrogen and potash. A nitrogen supply is an essential for an agricultural nation, and many are the schemes for extracting it from the air, from seaweed, and other natural sources. If we were to choose one outstanding need of the United States to-day, it would probably be to increase and safeguard its necessary supply of nitrogen so that it could not be cut off, as in the period of the Great War, by a stoppage of our usual annual import of nitrates for fertilizer.

"The soil," says Professor Russell, of the Wisconsin Agricultural College, "is the great fundamental asset in our national wealth. Out of it come life and sustenance for the whole world of nature and mankind. . . . If human life is to receive adequate support from the soil, the soil-tiller must feed his soil as he feeds his flocks."

PIONEERING

Most interesting of all is the pioneering which is being carried on as to the essence of all matter and the laws which control its action. For the story of the "Worlds Within Worlds," the molecules, atoms, and electrons of which all matter is made up, you must turn to the section with that title in Volume XI. As we have seen in our study of fuel and of electricity, the cry of the world is for energy. When, therefore, a physicist succeeds in making artificial lightning in his laboratory, he is doing more than imitate Nature for the sake of seeing that he can do it. In this man-made flash of lightning a force is released for a fraction of a second which is more than ten million horse power, or greater than the total electrical power of the country. When he succeeds in dispelling a fog by spraying into it electrically charged grains of sand, he is producing on a small scale an effect on the weather which may be of far-reaching importance.

The research of to-day provides the inventions of to-morrow; the inventions of to-day are translated into practical commercial use in the industries of to-morrow. All find their source in that spirit breathed into man,

> "Lifting him up from his low estate,
> With masterful passion, the wish to create."

Official Photo, U. S. Army Air Service

PIONEERING — MAN IN HIS MACHINE AT CREST OF MOUNT JEFFERSON

F.R.HARPER

Y0-CHR-682